ENVIRONMENTAL IMPACT STATEMENT

FOR THE

HAWAII
GEOTHERMAL RESEARCH STATION
UTILIZING THE HGP-A WELL
AT
PUNA, ISLAND OF HAWAII

DEPARTMENT OF PLANNING AND ECONOMIC DEVELOPMENT

ENVIRONMENTAL IMPACT STATEMENT FOR GEOTHERMAL RESEARCH AND DEMONSTRATION FACILITY UTILIZING THE HGP-A WELL AT PUNA, HAWAII

Prepared for the Department of Planning & Economic Development
of the State of Hawaii

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PREFATORY NOTE

This Environmental Impact Statement utilizes much of the information presented in An Assessment of Geothermal Development in Puna, Hawaii, a report of the Hawaii Geothermal Project issued in January 1977. Data obtained from subsequent testing of the experimental well HGP-A have been added, as well as statements concerning (i) measures which will be taken by this project to minimize potentially adverse environmental effects of using heat from the well to generate electricity; (ii) alternatives to pursuing this project; (iii) the social benefits and costs of geothermal development in Hawaii; and (iv) governmental controls over such development. Since the environmental impact of the geothermal development which this project intends to stimulate so greatly exceeds the impact of the project itself, much of the E.I.S. is devoted to "big picture" considerations.

THE PROJECT IN BRIEF

The project covered by this Environmental Impact Statement is a research and demonstration activity jointly undertaken by the HGP-A Development Group, consisting of the State of Hawaii, the County of Hawaii, and the University of Hawaii, with the Hawaii Electric Light Company of Hilo (HELCO) participating in an advisory capacity. HELCO is a subsidiary of the Hawaiian Electric Company (HECO). The project objectives are to ascertain the dimensions and characteristics of a geothermal reservoir in Puna, Hawaii, discovered by the University of Hawaii and to test or demonstrate various economic uses of the new resource. About three megawatts of the electric energy produced by the well already in existence on the 4-acre site accommodating the project will be sold to HELCO; the purpose of the project, however, is scientific -- to investigate the geothermal resource and its applications -- rather than commercial.

It is anticipated that a contract with the U.S. Department of Energy to design, construct and operate the research and demonstration facility will be signed with a target date of March 1, 1978. Figure 1 is the summary schedule for the project, which was submitted by the HGP-A Development Group and approved by the U.S. Department of Energy. According to current planning, the design and construction phase will require two years. The system design will be completed by the end of 1978, and construction is scheduled to begin on March 1, 1979, and be completed by March 1, 1980.

The operation and maintenance of the power plant will then be contracted to HELCO for two years. During this period, data will be gathered to determine the efficiency of a small geothermal electric generator system. These data can also be used in the comparison with other small generating systems utilizing other conversion technology. At the end of the two-year operation

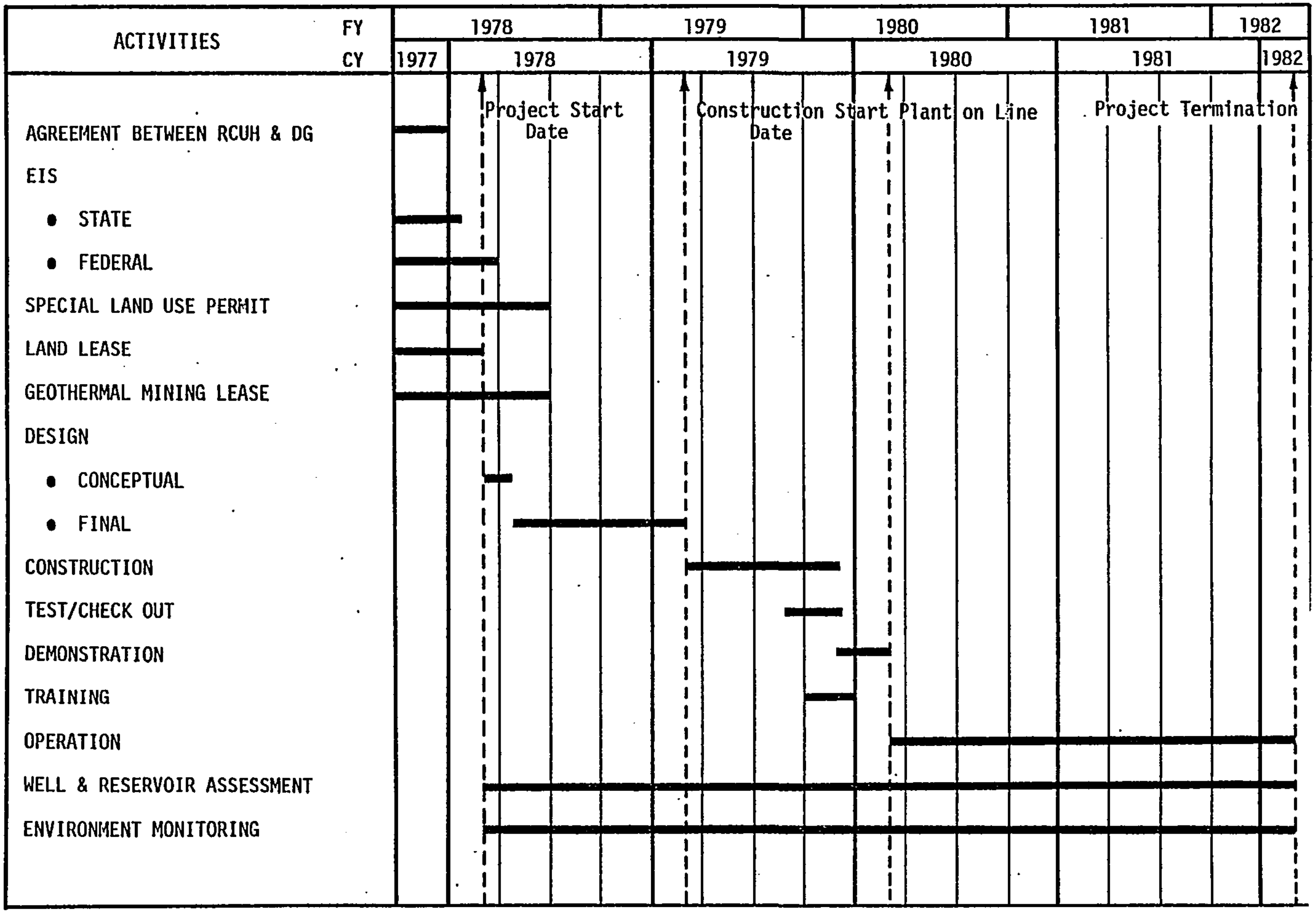

FIGURE 1: SUMMARY SCHEDULE FOR THE HAWAII GEOTHERMAL RESEARCH AND DEMONSTRATION FACILITY

period -- March 1, 1982 -- a decision will be made, with the approval of DOE, for the disposal of power plant equipment.

The site (Tax Key 1-4-01:2, portion) is off the Pohoiki Road, about 4 miles east of Pahoa, on land now owned by the Kapoho Land and Development Company which will be bought or leased by the State of Hawaii.

When completed, the facility will include a generating unit which will utilize steam from the well to turn a turbine linked to a generator, plus a system of pipes which will direct the geothermal fluid to areas within the 4-acre plot where various applications of geothermal energy (such as cooking fruit, sterilizing food containers, freeze-drying coffee, processing wood) can be tested out. A detailed description of the facilities proposed is appended. (See Appendix B).

1. THE NATURE, SIGNIFICANCE AND FUNDING OF THE PROJECT

Scientific exploration has established the existence of geothermal resources on the Island of Hawaii. First, in 1973, a 4,000 foot exploratory well drilled in the Hawaii Volcanoes National Park by Dr. George Keller, under a grant from the National Science Foundation, demonstrated that at depth a heat gradient existed which, projected to areas well below sea-level, would generate steam -- if sufficient water penetrated the rock at that depth.

Then, in the first half of 1976, the Hawaii Geothermal Project, University of Hawaii, drilled a 6,400 foot research well in Puna, down some 5,800 feet below sea-level. The well, designated as HGP-A,[1/] tested out with temperatures in excess of 600 degrees Fahrenheit, possessing a fluid source which can be flashed into steam with a wellhead pressure sufficient to power an electric generating unit of approximately 3.8 megawatts -- in itself a resource of

1/ The location of HGP-A is shown on Figure 4, below. It bears the property tax map number 1-4-02:2 (por.).

some commercial value, but more important as evidence that a larger development of geothermal resources may be economically feasible on the Big Island.

Geophysical and geological evidence suggests that other areas of the Island of Hawaii besides Puna and the Hawaii Volcanoes National Park (where economic exploitation of resources is not permitted) have geothermal potential. In fact, on the basis of that evidence the Hawaii Geothermal Project had planned to drill at two additional sites, on the southwest rifts of Kilauea and of Mauna Loa, but abandoned this more ambitious program of exploration for lack of funds. It is now proposed to conduct extensive tests of HGP-A, the experimental well, and to install and operate a wellhead generator with a variable capacity of between two and ten megawatts for the purpose of gaining operational knowledge about the production of geothermal energy on the Island of Hawaii and to demonstrate the feasibility of operations in a rift zone. Up to three megawatts of the electricity generated, surplus to the needs of the geothermal station, will be purchased by the Hawaii Electric Light Company (HELCO). The electricity will be fed into the HELCO transmission system which serves the Island of Hawaii. It is anticipated that up to 90 percent of the project will be funded by the federal government, with the State of Hawaii contributing $400,000 and the County of Hawaii $100,000.

If funds are sufficient, application of geothermal energy to uses other than the generation of electricity may be tested at the station. These uses involve direct utilization of the entire fluid obtained, or use of the flow of hot water after it has left the generating unit and before it is directed back into the ground.

No additional drilling is presently planned by this project for the 4-acre site on which HGP-A is located, but one or more step-out wells may be drilled by others in adjacent acreage to test the size of the geothermal reservoir.

A long-term purpose of the project is to further the development of geothermal resources on the Island of Hawaii, not only those tapped by HGP-A, but also the reservoirs which may lie elsewhere along the rift zones in Puna. For that reason this E.I.S. considers the environment of the entire Puna District, though it does examine with greater particularity the conditions of water, air, flora and fauna of the immediate vicinity of the project area on the lands of the Kapoho Land and Development Company, approximately 4 miles southeast of the village of Pahoa.

INTEREST OF THE STATE IN NEW ENERGY SOURCES

The paradoxical position of the State of Hawaii with respect to energy has been much commented on since the national petroleum crisis in the winter of 1974. Naturally, Hawaii is lavishly supplied with energy from the sun, tradewinds and the action of the sea, but completely lacks the fossil fuels used as standard energy sources by contemporary technology. A few small hydroelectric facilities on Kauai and Hawaii produce some power on those islands, and on some sugar plantations, notably on the Island of Hawaii, burning the bagasse (left in the sugar mill after the juices have been extracted from the cane stalks) generates considerably more -- but the combined contribution of these two indigenous energy sources to the State's consumption of BTU's is but a tiny portion of the total.[1/] Well over 90 per cent is derived from petroleum products, the bulk of which is refined on Oahu from crude oil imported from abroad and then sold at prices above those which generally prevail on the continental U.S.

1/ In 1974, the amount coming from hydroelectric power was estimated at 0.03 per cent while 0.31 per cent of the total energy consumption came from the burning of solid wastes, i.e. bagasse. See flow chart in Alternate Energy Sources for Hawaii (Honolulu, University of Hawaii and Department of Planning and Economic Development), February 1975, p.25. Other sources indicate somewhat larger inputs from hydroelectric and bagasse, but still amounting to less than 10 per cent of the total.

Partly as a consequence of the high cost of petroleum, electricity rates in Hawaii are among the very highest in the United States. The average here is brought up by the high rates in the neighbor islands. For example, as of August 12, 1977, residences using only 500 kilowatt-hours in a month would have paid these bills: on Oahu, \$25.18; Maui, \$34.45; Hawaii, \$37.71; Lanai, \$36.03; Kauai, \$37.84; and Molokai, \$39.29.[2/]

Since 1974 there has been a heightened concern about Hawaii's virtually complete dependence on petroleum shipments, not only the costliness but also the uncertainty of maintaining the vital flow of oil under the hazards of political instability in the Middle East and in Southeast Asia. A variety of energy sources indigenous to Hawaii (as well as nuclear power plants, which apparently are not yet scaled down to a size economical for Hawaii) are being investigated. These include solar collectors; wind energy conversion; solid waste and biomass conversion; utilizing the heat differential in off-shore ocean waters; and geothermal energy.

These potential new sources of power offer promise of supplying significant quantities of energy, taking "significant" to mean 10 per cent or more of the total electrical energy demand of the State.[3/] At this writing, geothermal power seems to offer greater possibilities of near-term development to economic significance than any other indigenous energy source, even though solar heat is the first to be used, already being utilized in many homes in Hawaii to heat domestic water supplies, and the use of bagasse for generating electricity may be expanded.

2/ Rates supplied by the Hawaii State Public Utilities Commission. For comparisons with Mainland cities, see Federal Power Commission, Typical Electric Bills (Washington, D.C., annual).

3/ Comparison of these potential energy sources is made in a 1975 report of the (Hawaii) State Advisory Task Force on Energy Policy in Alternate Energy Sources for Hawaii (Honolulu, Natural Energy Institute of the University of Hawaii and the Department of Planning and Economic Development).

The exploratory well, HGP-A, gives preliminary indication that one or more geothermal reservoirs may exist in Hawaii, having a temperature and pressure adequate for commercial exploitation, either in the production of electric power or by direct applications of the hot water/steam coming from wells tapping the resource. It has yet to be established, however, that a reliable power source can be located satisfactorily in an active volcanic zone; this will be tested. Further, the projected research and demonstration facility will serve as a research tool for appraising the geological and engineering characteristics of the test well as used in production. Further, the facility can be used for researching modes of direct application of the heat, as in agricultural and industrial uses.

By helping to define the nature and extent of the geothermal resource in Puna, and by demonstrating how the resource may be used in electrical and non-electrical applications, the facility may be instrumental in shaping the development of this new energy source and in setting local standards for its utilization.

2. ENVIRONMENTAL SETTING: THE DISTRICT OF PUNA PRIOR TO GEOTHERMAL DEVELOPMENT

A. The physical environment generally.[1/]

The Puna District, site of the exploratory geothermal well, is the easternmost projection of the Island of Hawaii, comprising approximately one-eighth of its 4,038 square miles. Much of the District is formed by undissected volcanic uplands, that of Kilauea to the north and that of Kalapana to the south, but between, running from the Kilauea Caldera Complex eastward to the sea around Cape Kumukahi, is the Puna cone and crater area, marked by pu'us and craters of recent eruptions, notably that of 1955. Figures 2 and 3 show the historic lava flows on the Island of Hawaii and in east Puna.

With an estimated mid-1976 population of 7,800, Puna is the second most populous of the nine districts of the Big Island -- some distance behind South Hilo District, where approximately 40,000 people live. The basis of comparison is made clearer by noting that only two "towns" in Puna, Kea'au and Pahoa, contain as many as -- and not much more than -- a thousand people. Most of the residents of Puna live near the chief enterprise of the area, the Puna Sugar Company, or in widely spaced clusters of houses along the coast. Only a few have homes in the new and largely undeveloped subdivisions which have been drawn across the map of the District. There are only a dozen houses within a mile radius of the drill site itself.

Over half of the Puna District is thinly covered by the histosols, sparce organic soils, which commonly occur on geologically young lava lands. In a band stretching across the west central part of the District -- to the west of the well site -- is an area of entisols, weakly developed soils found on old beach sand and volcanic ash. On this land has developed an area of marked environmental contrast: there is fertile soil and lush vegetation over the lower-lying fields,

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1/ Much of this section is derived from a report of the Hawaii Geothermal Project, Environmental Baseline Study for Geothermal Development in Puna, Hawaii, (University of Hawaii, September 1976).

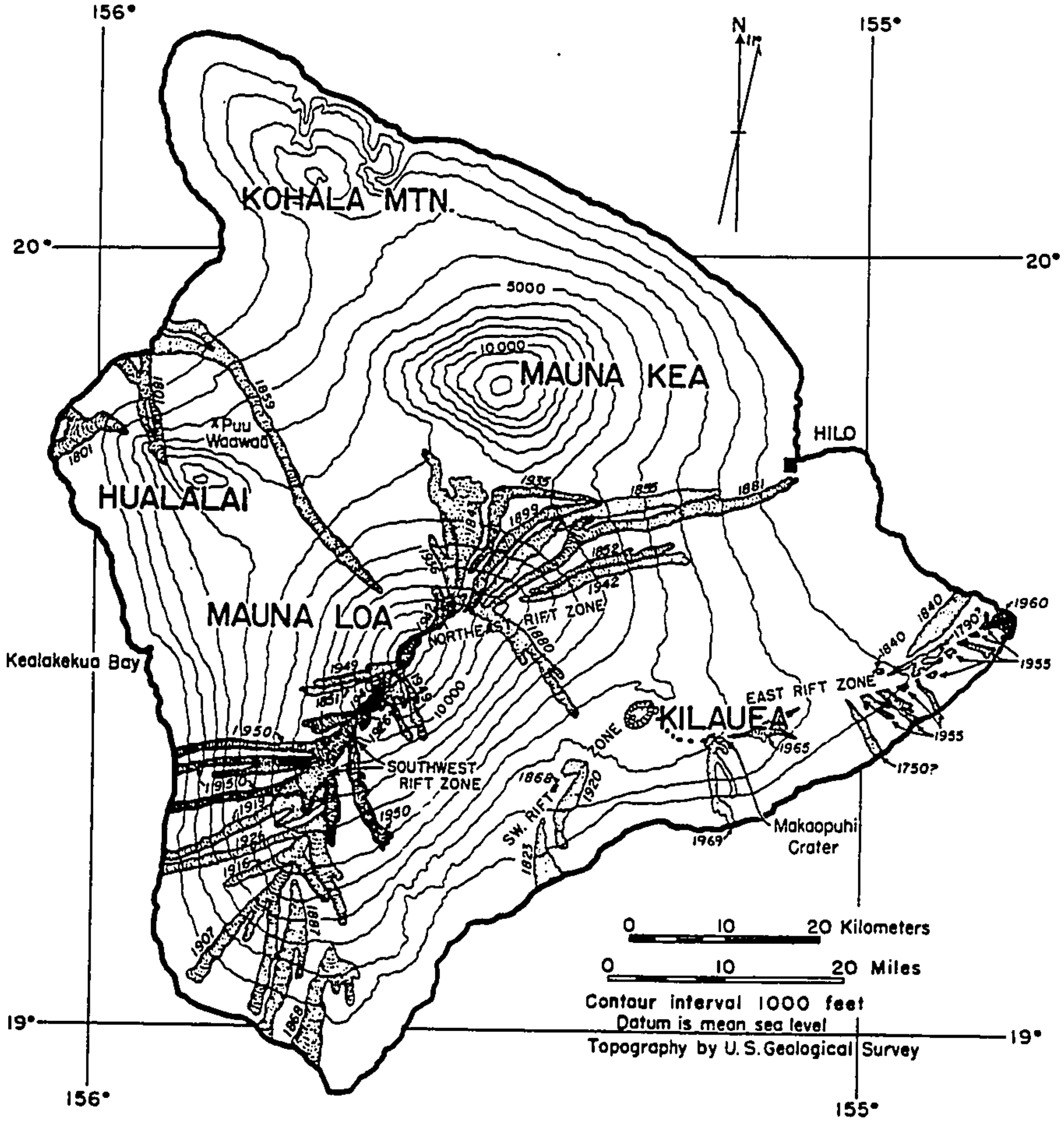


FIGURE 2: Map of the Island of Hawaii, showing the five major volcanoes that make up the island, and the historic lava flows.

From: Volcanoes in the Sea, Gordon A. Macdonald and Agatin T. Abbott, University of Hawaii Press, p. 52.

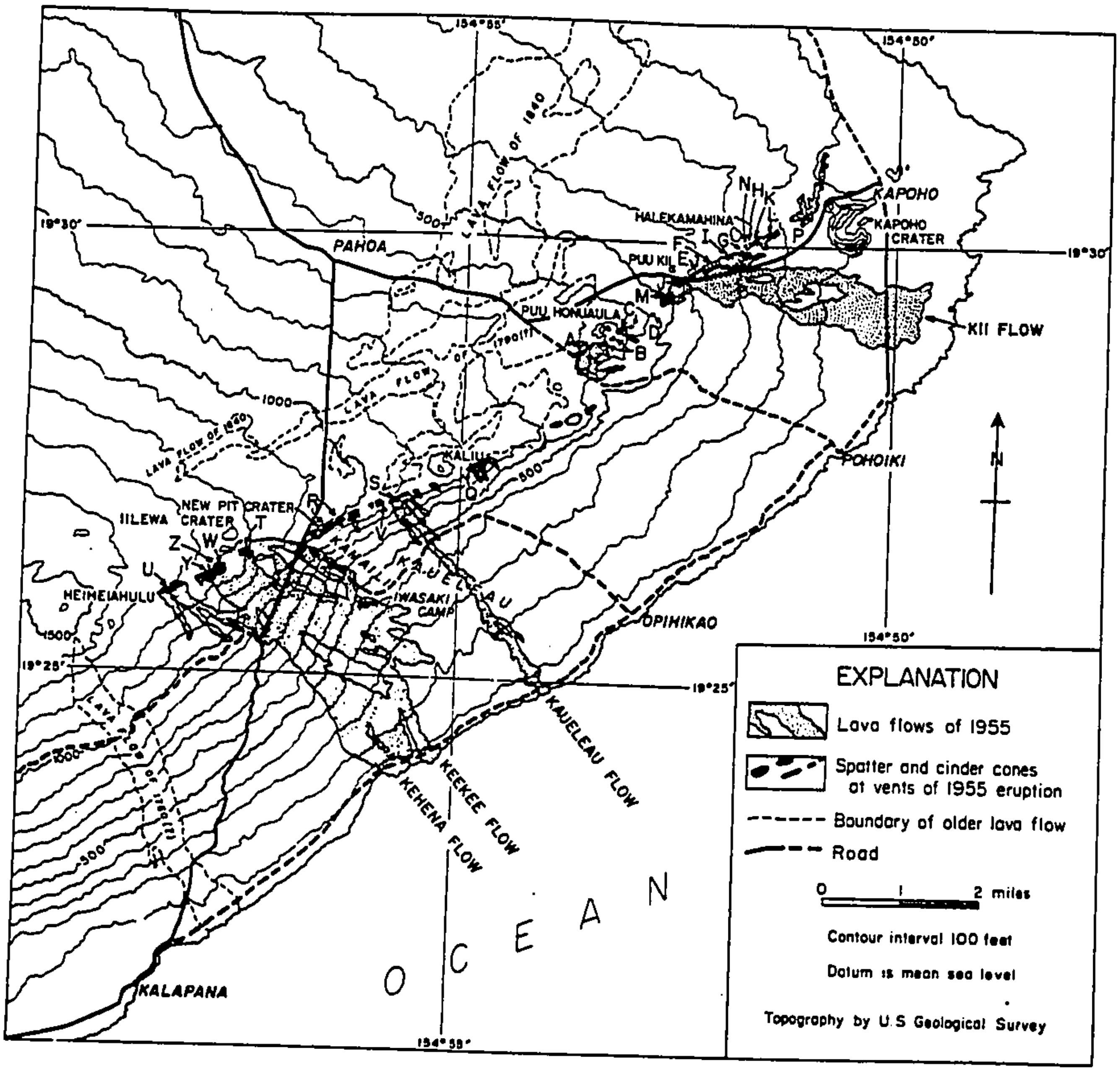
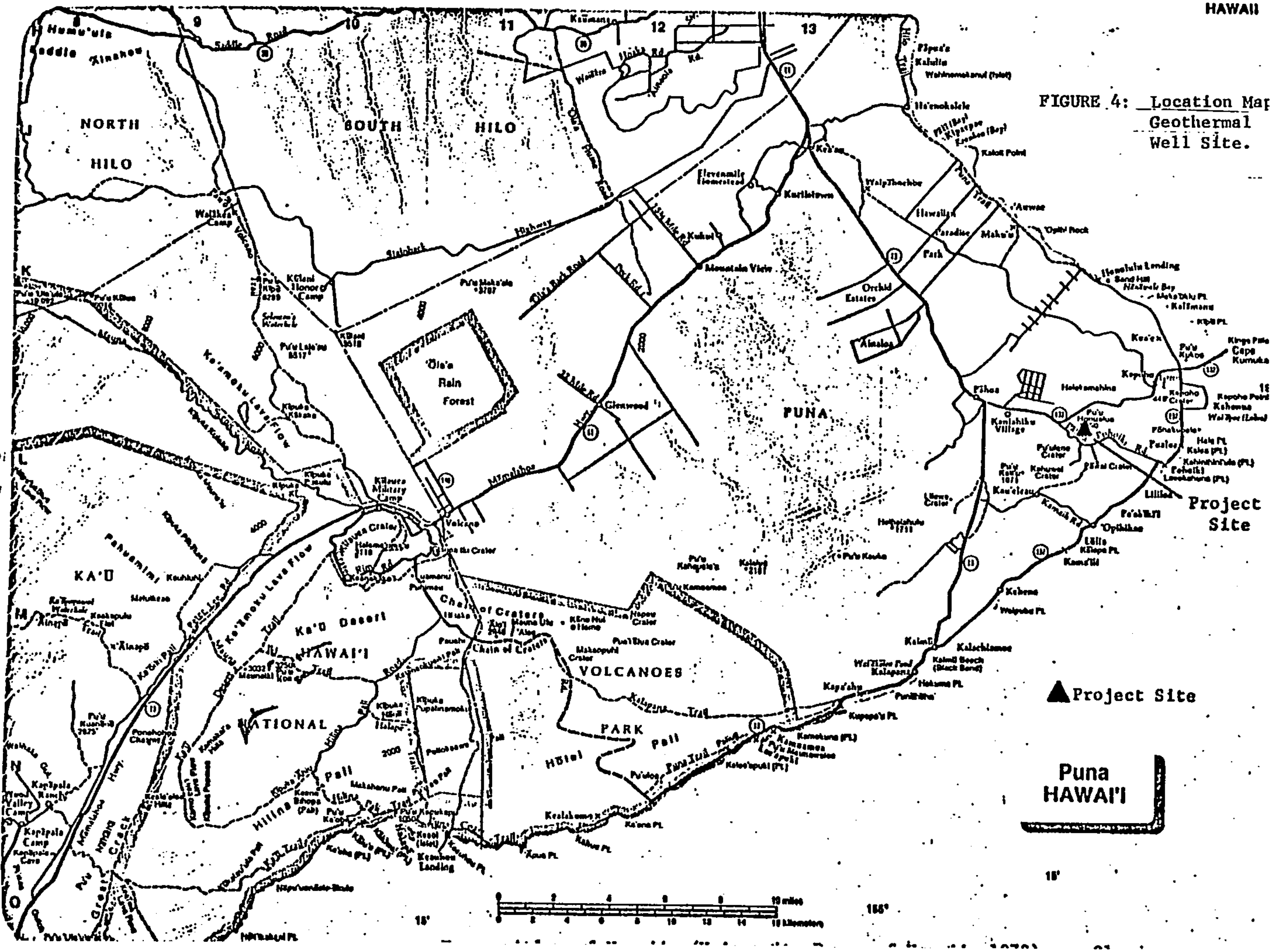
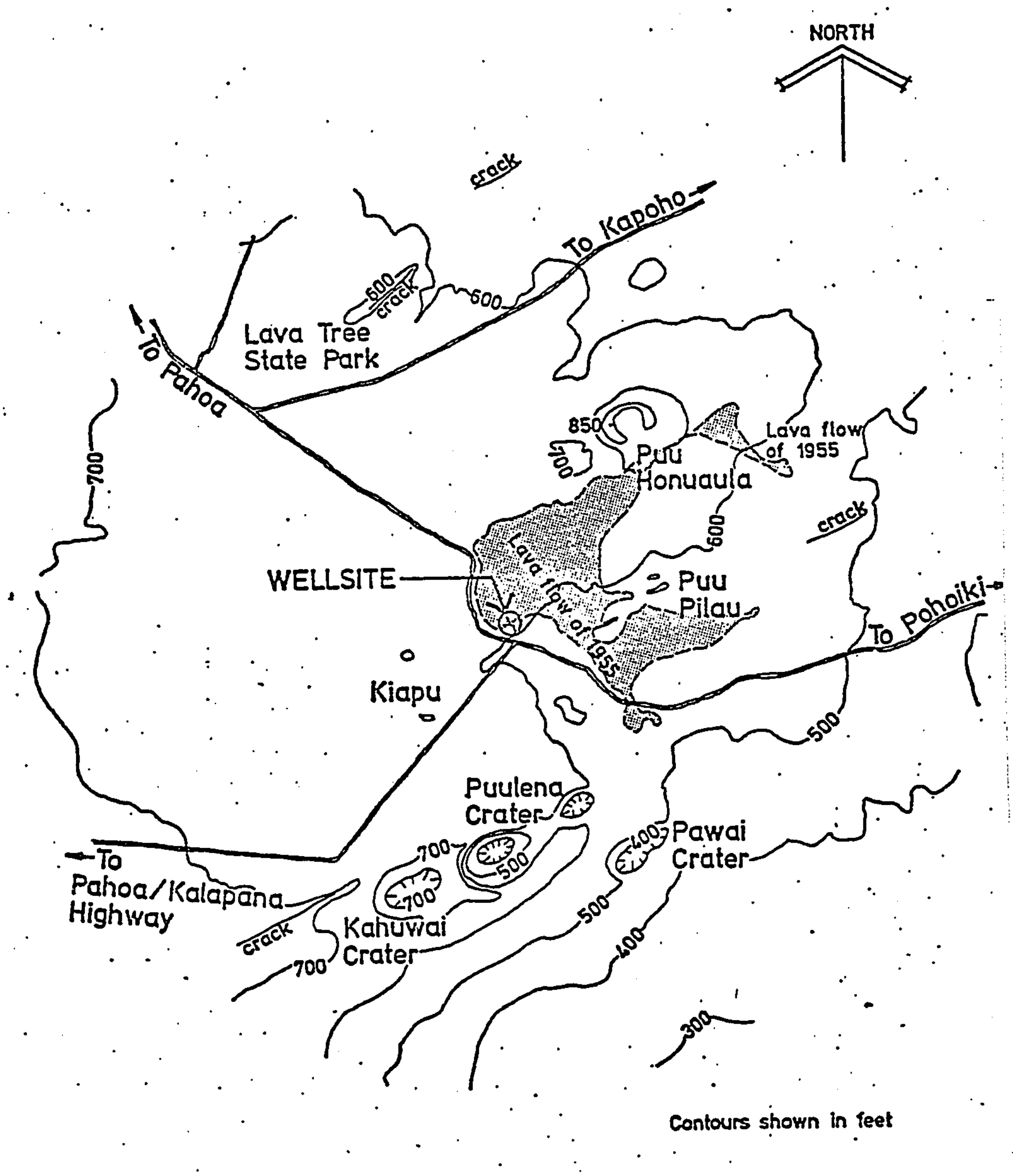


FIGURE 3: Map of east Puna (the east rift zone of Kilauea), showing the lava flows of 1955 in relation to older historic flows.

From: Volcanoes in the Sea, Gordon A. Macdonald and Agatin T. Abbott, University of Hawaii Press, p. 86.

FIGURE 4: Location Map Geothermal Well Site.





Source: Hawaii Geothermal Project Well Completion Report, HGP-A, Kingston, Reynolds, Thom & Allardice, Ltd. (Auckland, N.Z., 1976)

FIGURE 5: Site Location, Experimental Well HGP-A.

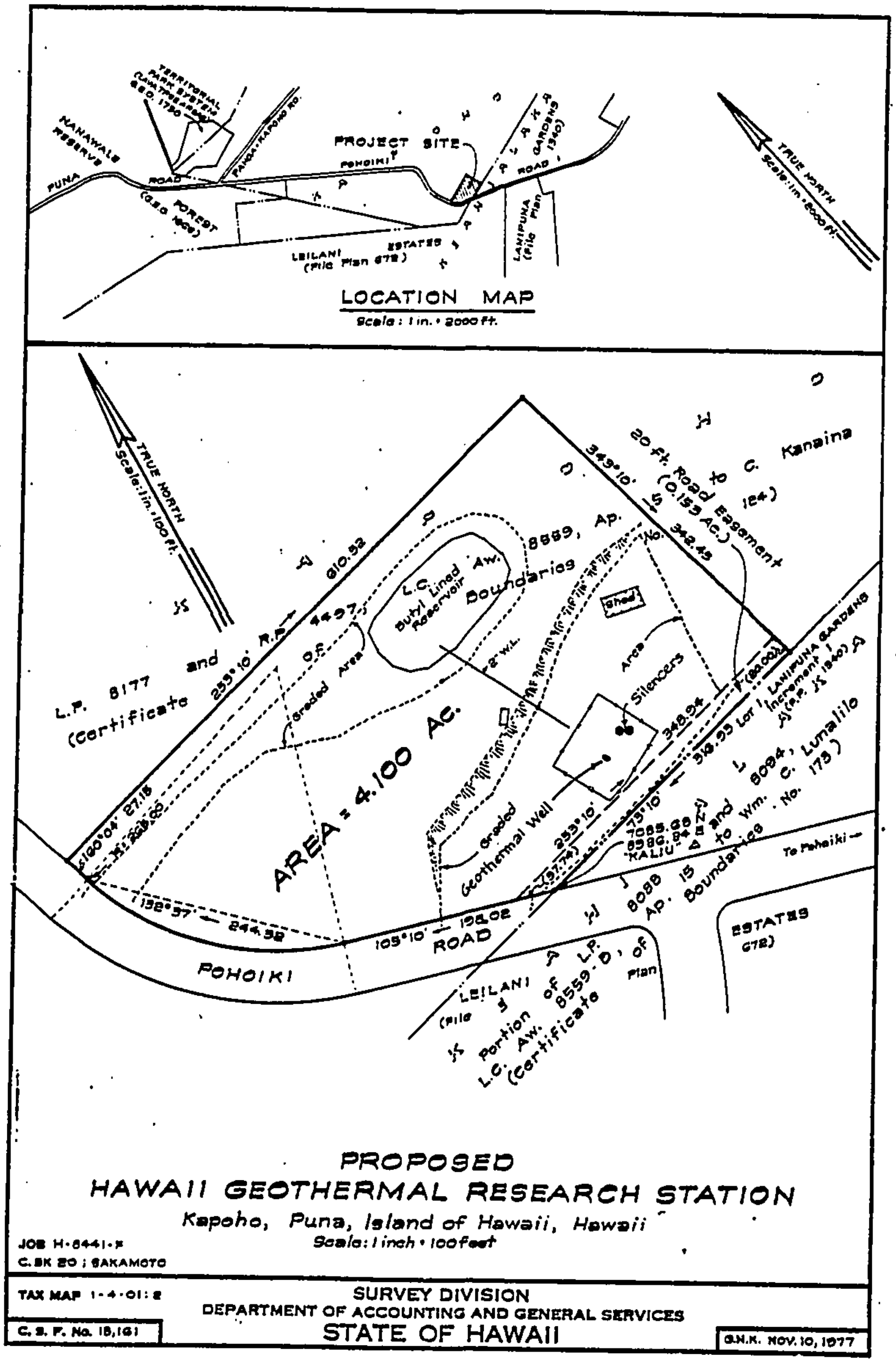


FIGURE 6: Map of 4.1-Acre Parcel -- Site of HGP-A.

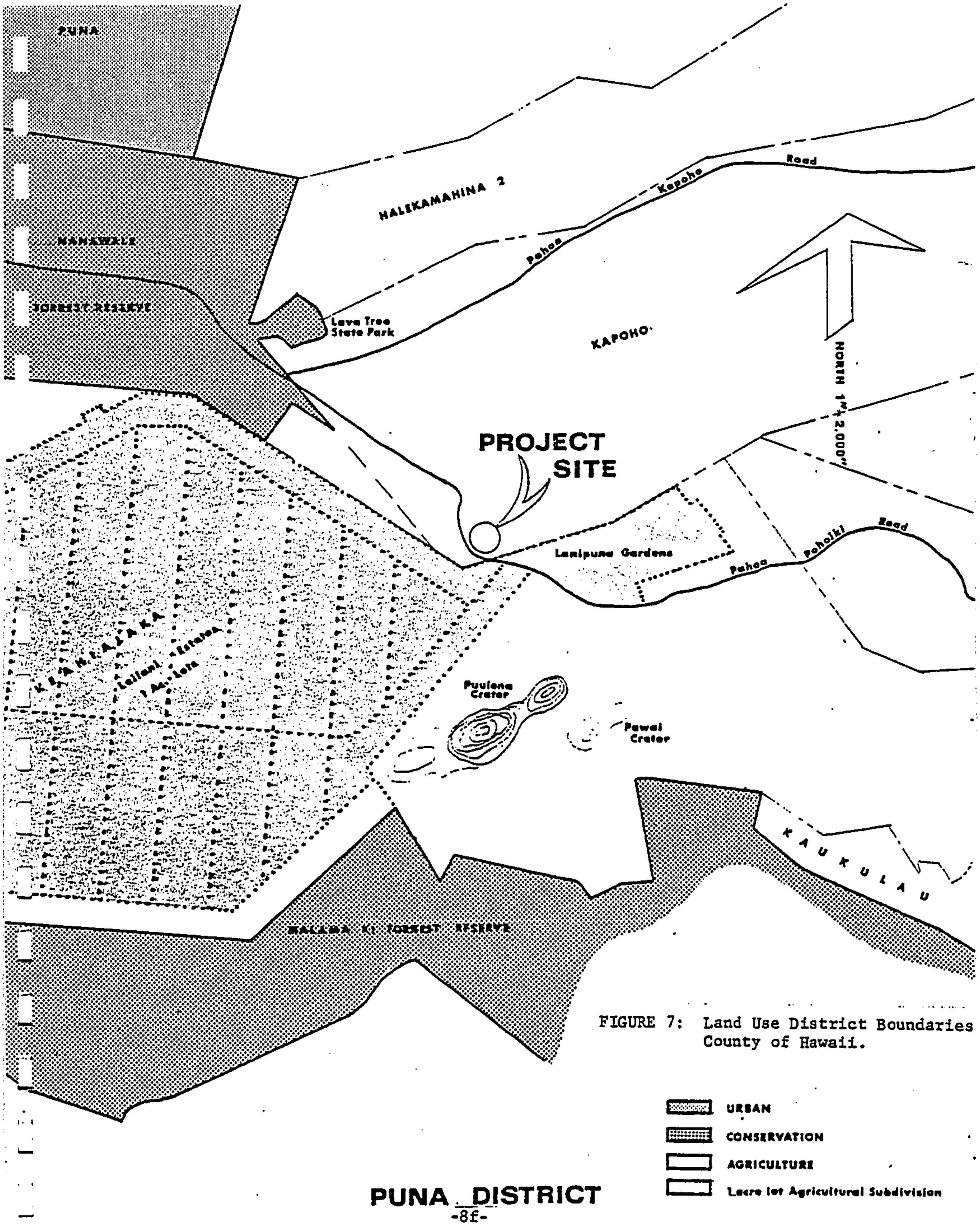


FIGURE 7: Land Use District Boundaries County of Hawaii.

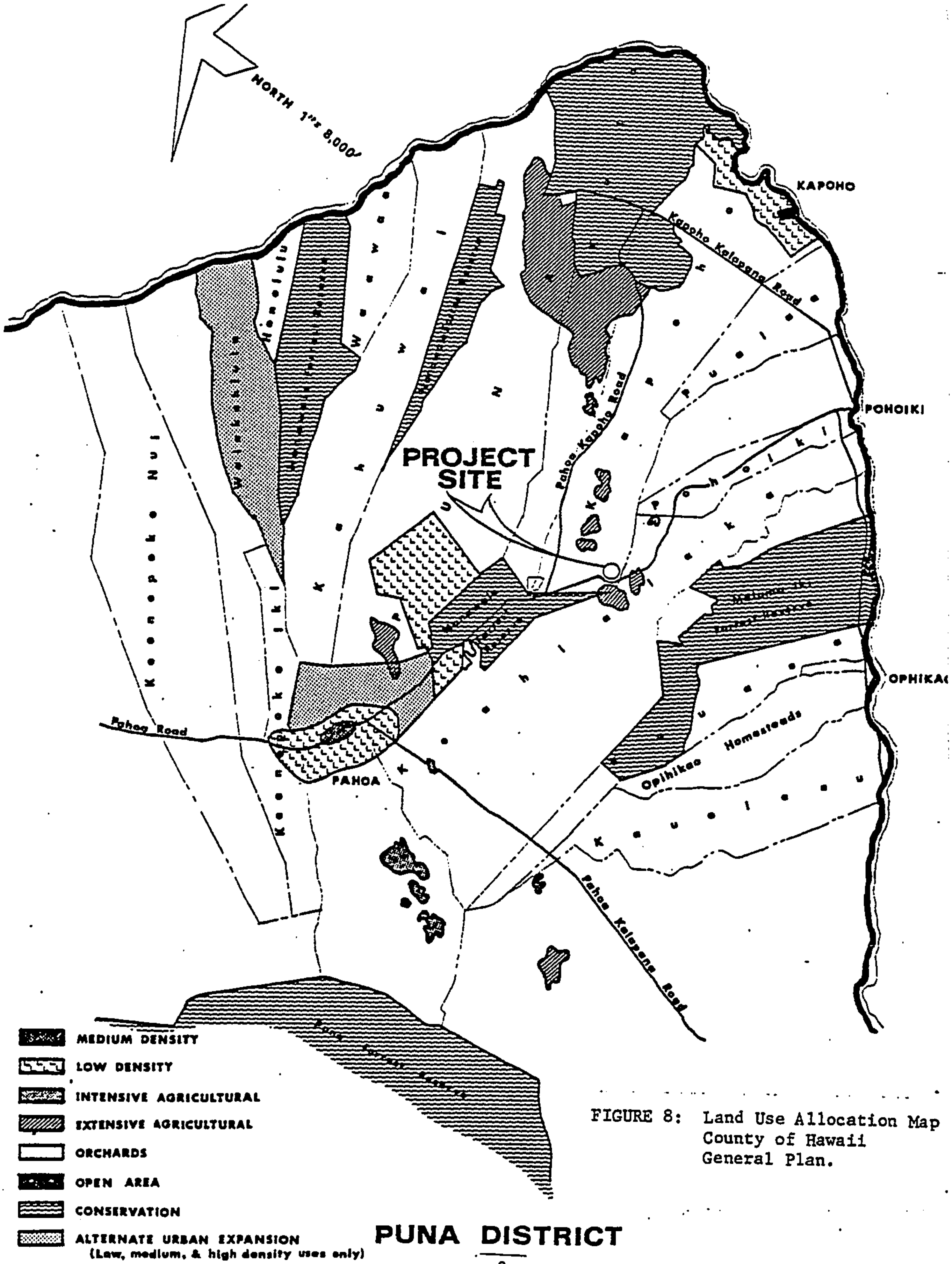


FIGURE 8: Land Use Allocation Map
County of Hawaii
General Plan.

while the geologically younger upper slopes are dotted with <u>ohias</u>, which are the most common and most widely distributed species of native trees in Hawaii. Despite abundant rainfall, much of the area around the geothermal site, where recent lava flows have blackened the land, is a suburban wilderness of empty subdivisions. In a few places, thin plumes of steam mark vents where the underground heat of the area escapes into the atmosphere. To the east, however, lies one of the major papaya areas of the State, and to the west are productive sugar lands. Along the coast, the ocean beats against black lava cliffs. Where there are beaches, they, too, are usually black, produced by the explosion of hot lava meeting the sea.

The fact that the project area was covered by lava flows as recently as 1955 necessarily enters into any consideration of long-term development. There is yet no means of estimating the probability of another lava flow, or of a disabling earthquake, over the decades that a geothermal field may remain in operation. However, the vulnerability of a geothermal field to such destructive forces is not total. While any surface installations -- the gathering lines, separators, condensers, generators, etc. -- may be destroyed by quakes or by flows which are not diverted (as by protective dikes), the wells themselves are not necessarily so vulnerable. An earthquake of 7.2 Richter-scale magnitude was experienced as HGP-A was being drilled and scarcely affected the operation, so stable was the bore. Since lava flows seldom exceed 15 feet in depth, the wellhead could be protected by a reinforced cement casement; even if a well site should be innundated with lava, as long as the wellhead was clearly marked it could be opened up again in several years, after the lava cooled.

B. Groundwater supply*

The hydrology of the Puna District is not well established. The general hypothesis, as in other portions of the Hawaiian Islands, is that the area is underlain by a supply of basal water floating on salt, with a relatively narrow band of dike-confined water (not floating on salt water) running across the southern part of the District, and with a coastal zone of brackish basal water west of Kalapana.[2/] However, there is only limited use of the local ground water supply for domestic purposes; the water supply for Pahoa and other communities in the southeastern part of Puna is pumped in from the adjacent District of South Hilo.

Indeed, sampling of seven water wells within a radius of about two and one-half miles from the geothermal well site revealed high salinity (above 270 mg. per liter) in four of the seven and at depths no greater than a few hundred feet below sea level. While salination of basal water due to inter-mixing with underlying salt water is a common phenomenon in coastal areas, where unconfined fresh water lenses are thinnest and easily perturbed by tidal effects or heavy pumping, the relatively high salinity of inland wells (such as Malama-ki, Geothermal No. 3, and Airstrip Well -- see Figure 9) suggests that the Ghyben-Herzberg lens, in which fresh water floats on salt water, if it exists in the portion of Puna around the exploratory well site, is subject to greater intrusion by salt water at the high temperatures of this geothermal regime.

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* Research on this section was done by Dr. Robert W. Buddemeier, Associate Professor of Chemistry, Dr. Peter Kroopnick, Associate Professor of Oceanography, Dr. Theodorus Hufen, Research Associate in the Hawaii Institute of Geophysics, and Dr. L. Stephen Lau, Director of the Water Resources Research Center.

2/ H. T. Stearns, Geology of the Hawaiian Islands, (Honolulu, Department of Land and Natural Resources, 1967. Reprint of Bulletin 8 of 1946).

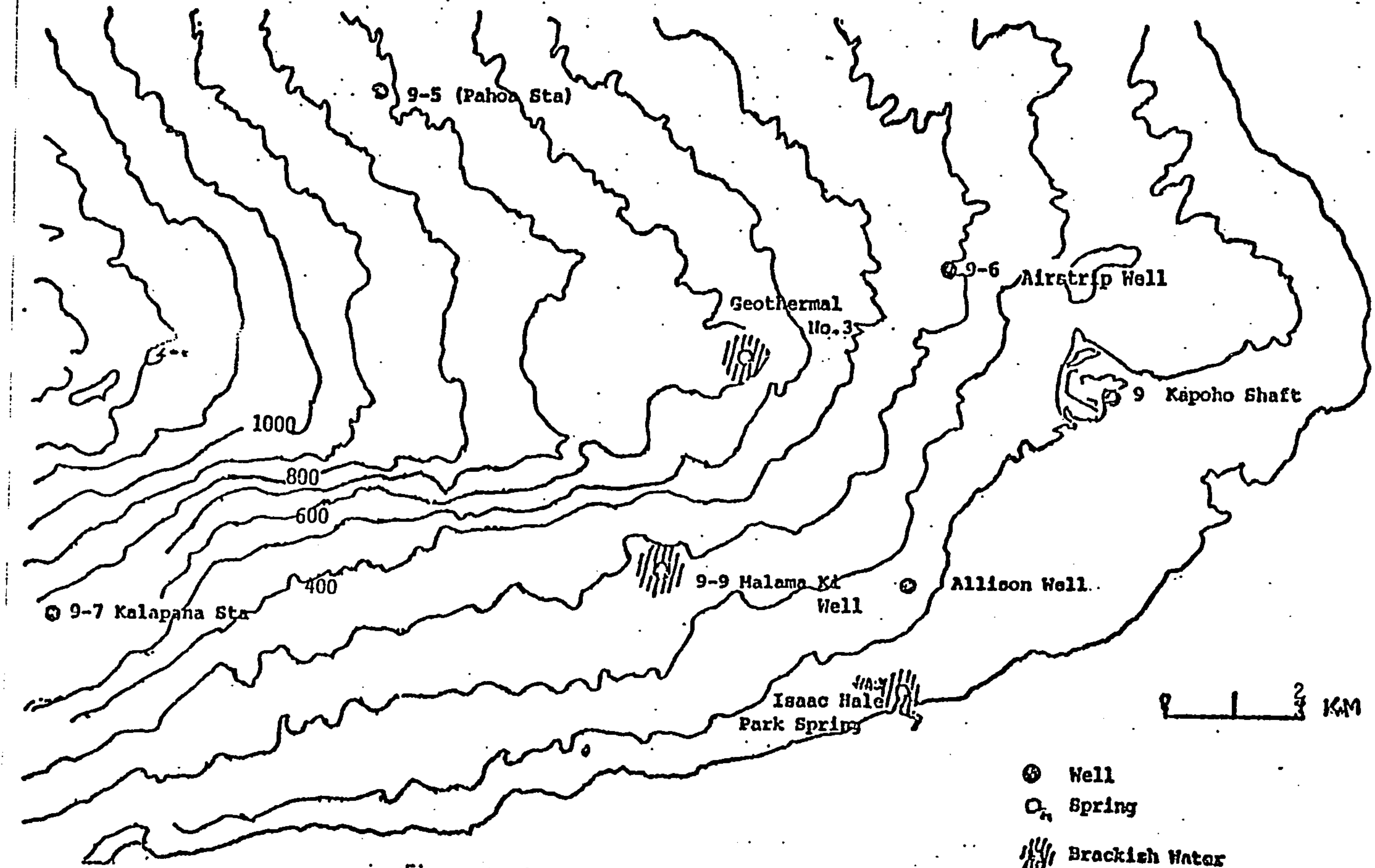

Figure 9. Location of Sampled Wells and Spring, Puna, Hawaii

Groundwater in the area and, for control purposes, rainwater samples as well, were tested not only for the chemical characteristics (Table 1), but also for its microbiological qualities (Table 2). Moderately high values for coliform bacteria were recorded at Isaac Hale Park Spring, where the geothermally heated pool is used for casual bathing, and a much higher count was observed for the sample from Allison Well. Otherwise, no results of a cautionary nature were reported in the baseline study. As testing of the exploratory geothermal well proceeds, the existing water wells will be monitored for changes in chemistry or microbiology which may accompany the test flows.

C. Geothermally-related chemical toxicants in air, water, soil*

Particular attention must be given to ascertaining if the chemicals commonly found in geothermal water or steam pose a threat to the environment. From May 1975 to date, the environs of HGP-A have been tested for mercury and toxic gases, particularly the sulfur compounds known to be emitted in geothermal areas. With respect to the fixed gases -- SO_2 and H_2S -- there has been no evidence of change from pre-drilling through recent flashing experiments (Table 3). These values have been consistently at or below detection thresholds and well under hazardous levels in spite of the proximity (25 miles) of natural vents in the Volcanoes National Park which supply these sulfurous gases continuously. In these fumarole areas, the measurement during 1971-76 yielded peak values as high as 25 ppm for SO_2 and 5 ppm for H_2S. These toxic emissions apparently reach the HGP drill site area only infrequently and for brief periods. Their lack of persistence may be an important environmental consideration. Aside from convective

* Dr. Barbara A. Siegel and Dr. Sanford M. Siegel, respectively Associate Professor of Microbiology and Professor of Botany, jointly investigated potential effects on air quality, the soil and plant life in the area, with the assistance of Dr. Thomas Speitel, Research Associate in the Department of Botany, and the following students voluntarily worked with the Professors Siegel on geotoxicology testing: Willie Cade, Melvin Calvan, Anna LaRosa, Kapuanani Lee and Hope Stevens.

TABLE 1. CHEMICAL DATA ON GROUNDWATER AND RAINWATER

PUNA, HAWAII, PRIOR TO DRILLING

EXPLORATORY GEOTHERMAL WELL

OLD NO.	STATE NO.	NAME	DATE	T*	pH	Na**	K	Ca	Mg	Cl	HCO_3	SO_4	SiO_2	N***	P
9-5	2986-01	PAHOA STATION	1-6-75		7.30	36.0	2.72	1.58	2.7	13.5	48	21.1	50.0	0.252	0.078
9-7	2487-01	KALAPANA STATION	1-6-75	28.5	7.68	89.6	5.20	5.30	6.6	132.2	38	37.2	44.5	0.070	0.056
9	3080-02	KAPOHO SHAFT	1-6-75	25.5	7.80	85.8	6.60	42.4	37	16.9	372	20	53.6	0.378	0.233
9-6	3081-01	AIRSTRIP WELL	1-6-75	33.0	7.42	238	13.6	23.0	28	303.5	48	204	71.3	0.014	0.040
	2881	ALLISON WELL	1-7-75	37.5	7.35	216	10.8	13.4	15.	281	132	69.2	24.1	>14	<0.002
		ISAAC HALE PARK SPRING	1-7-75	36.0	7.75	2020	86.0	32.4	200	3534	56	507	81.5	1.218	0.016
9-9	2783-01	MALAMA KI WELL	1-7-75	52.3	7.02	2105	109	66.8	210	3811	144	471	100.7	0.280	0.006
		GEOTHERMAL Ø3	1-7-75	93.0	6.85	2050	190	76.8	52	3274	30	314	96.6	0.003	0.006
		RAIN AT KALAPANA STATION	1-6-75			4.5	0.25	0.25	0.75	7.2		~2.5	0	0.024	<0.002

*TEMPERATURE GIVEN AS °C

**CHEMICAL DATA IN mg/l

***NO_2 NO_3 as N

TABLE 2 MICROBIOLOGICAL QUALITY OF GROUNDWATER

PUNA, HAWAII, PRIOR TO DRILLING

EXPLORATORY GEOTHERMAL WELL

WELL/SHAFT NO.	STATE NO.	NAME	DATE OF SAMPLE	COLIFORM MPN No. per 100 ml	FECAL COLIFORM MPN No. per 100 ml	REMARK
9-5	2986	PAHOA	1-6-75	<3	<3	Unchlorinated sample
9-7	2487-01	KALAPANA	1-6-75	<3	<3	Unchlorinated sample
9	3080-02	KAPOHO SHAFT	1-6-75	460	<3	
9-6	3081	AIRSTRIP	1-6-75	<3	<3	
9-9	2783	MALAMA KI	1-7-75	<3	<3	
——	----	ISAAC HALE BEACH PARK HOT SPRING WATER	1-7-75	1500	7	
——	2881	ALLISON	1-7-75	≥24,000	93	Well bottom mud in sample

TABLE 3

TESTING FOR CHEMICAL TOXICANTS AT THE
HAWAII GEOTHERMAL PROJECT WELL: A CHRONOLOGY

DATE	STATUS OF WELL	FIXED GASES[1]		RESULTS OF ANALYSIS		MERCURY	
		SO_2	H_2S	Air[2]	Water[3]	Soil[4]	Plant[5]
May 1975	Pre-drilling	<0.5	<0.5	1.1	2.5	43-59	130/263[5]
May 1976	Post-drilling	<0.5	<0.2	1.2	5.0	141/356	160/571
June 1976	Preliminary well test	<0.5	<0.2	1	3.0	--	--
July 1976	Flashing	<0.5	<0.2	9.9*	4.6	--	--
November 1976	Well shut down	--	--	>10.0*	--	--	--
April 1977	Well shut down	<0.5	<0.2	--	--	--	--
July-Aug. 1977	Well shut down	<0.3	<0.2	0.8			

1 In ppm

2 In μg/m^3

3 In μg/l

4 In μg/kg

5 Nutgrass within 50m, Ohia-fern at ca. 100m distance.

* These high values for mercury, even when the well was shut down, seem to reflect elevated activity along the East Rift with the formation of new emission centers, such as Heiheiahulu, rather than emissions from the well.

and wind dispersal processes, these gases may be oxidized both photochemically and biochemically to sulfates, and the capacity both of soil microorganisms and vegetation for metabolizing these sulfur gases may contribute to ecological "detoxification."

The same consideration cannot be applied to mercury. It is a potential toxicant in any form, although more so in elemental and alkyl forms. Various figures have been cited for maximum allowable air mercury. Schroeder[3/] has suggested an 8 hour occupational limit of $10 \mu g/m^3$ but recommends no more than $0.1 \mu g/m^3$ for continuous exposure of the population at large. Applying a provisional Federal exposure value of $1 \mu g/m^3$ as a reference figure, it is obvious from Table 3 that HGP drill site levels were at threshold up to the flashing experiment, but it is also clear that up to the 22 July 1976 flashing, the mercury levels were area values not related to drill site operations. Hawaiian thermal areas are essentially like those elsewhere in the world with respect to mercury in air, water, soil and plants (Table 4), with norms tending to be appreciably higher than in nonthermal areas.

The upsurge of air mercury levels during flashing was originally thought to have been a "burst" releasing accumulated mercury at depth. During the July 1977 testing, it was not known that a new East Rift Zone emission center -- the Heiheiahulu spatter cone about eight miles to the east of the well -- had been active for some months. When that was made known, the cone was tested and found to be a highly intensive mercury emitter and the probable source of the relatively high level recorded at the flashing of HGP-A. Subsequent measurements, made in July-September 1977, show the presence at the well site not only of air mercury but also of SO_2 and H_2SO_4 -- although the well itself had been shut down

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3/ Schroeder, H., Air Quality Monograph No. 70-16, American Petroleum Institute, Washington, 1971.

TABLE 4

MERCURY LEVELS OUTSIDE THE HGP-PUNA DRILL SITE AREA:

COMPARATIVE AIR AND WATER DATA, 1971-1976

SAMPLE	HG CONTENT
Air	μg/m^3
Thermal	
Hawaii	0.7-40.7
Iceland	1.3-37.0
U.S.S.R. Kamchatka-Kuriles	0.3-18
Non-thermal	
Hawaii	0.04-0.3
Iceland	0.62-1.0
New York	$\leq$0.014
Cincinnati	0.03-0.21
Eastern Pacific (open sea-west of California)	$\leq$0.0007
Water	μg/l
Poipu Beach (Kauai)	2.1
Kuhio Beach (Oahu)	2.3
Nuuanu Stream	0.6
Oahu aquifer	<0.2
Rain, Hawaii, January 1972 Island of Hawaii, general	0.20-0.25
HVNP fumarole condensate, 1972	20-40
Western Atlantic, general	0.01-0.30
Hawaii aquifer (Puna)	$\leq$0.5

since May 1977. The presence of these toxic gases can only be ascribed to natural area contamination, not emanating from the well itself. Tests conducted since drilling of HGP-A began have yielded no evidence of a sustained build-up of mercury at or around the well site that can be attributed to geothermal energy development operations. The conclusion reached by the researchers is that "there is no reason to assume that HGP-A itself has any negative emission features beyond nuisance value H_2S and noise, but is (itself) influenced by its proximity to natural geotoxicant sources."[4/]

D. Flora and Fauna

(i) Plants*

While there are trees on the Puna landscape -- the ohia just noted, roadside or backyard mangoes, citrus, monkeypods and other ornamentals -- the District is by no means forest-covered. There are four state forest reserves in the District (Nanawele, Malama-ki, Keauhohana and Puna), but only the latter is extensive and none rate among the choice timber areas of the Big Island. Norfolk pines have been planted east of Pahoa in an attempt to supply the local Christmas tree market, but they have not flourished.

It was beyond the resources of the Hawaii Geothermal Project to assess the lesser flora of the Puna District in any detail. However, an area within a mile of the drill site was examined, and it seems sufficiently representative of those inland sections of the District which are not either in cultivation or

4/ S. M. and B. A. Siegel, "Emissions at HGP-A and Natural Vents, July-August 1977," Hawaii Geothermal Project Geotoxicology Supplement (HGP 4.1), August 22, 1977, p. 4. Suppression of noise and smell is discussed at pp. 41-42.

* Research on this section was done by Barbara A. Siegel and Sanford M. Siegel, assisted by Thomas Speitel and the following students: Willie Cade, Melvin Calvan, Anne LaRosa, Kapuanani Lee and Hope Stevens.

well populated -- and these relatively empty places comprise the bulk of the District -- to warrant inclusion in this description of Puna at large.

The well site is on an exposed lava flow of 1955. The undisturbed part of the flow consists of barren aa, covered by a dense growth of lichens, with scattered ferns and ohia lehua. Further off, around Lava Tree State Park approximately three-quarters mile to the west, there are areas of forest, consisting primarily of ohia, the size of the trees being related to the age of the underlying lava flow. Hence, most trees are small to medium height, but there are infrequent kipukas (islands of growth on land not subject to recent volcanism), in which some trees reach up to 100 feet. The groundcover around the ohia trees consists largely of false staghorn ferns, grasses and several species of wild orchids. Around the larger trees are some treeferns and ieie vines (Freycinetia arborea). All these endemic species are common to areas of Hawaii covered by lava flows of no great age.

In locations disturbed by roads, footpaths, trails and bulldozer tracks, however, there is a heavy admixture of introduced trees, shrubs, vines and grasses. Such exotic flora are found, for example, in the vicinity of Lava Tree State Park and in many areas downslope from the well site. This exotic plant population includes mango trees, papayas, guava, bamboo, kukui trees (Aleurites moluccana), sugar cane, bananas, Indian pluchea, Jamaica vervain, and sensitive plant (Mimosa pudica). A stand of Norfolk pines, already noted, rises between the well site and the Park, and there are groves of albizia along the road and at the Park.

It is impossible to make an absolute determination as to the absence of endangered and threatened species of plants within any area of appreciable size around the well site. However, in the process of making baseline studies of possible geotoxicants sometimes associated with geothermal activity, quadrat and transect analyses were carried out in May 1975 and re-examined in January 1976 at the well site.[5/] The genera of plants found at the site, identified in consultation with Dr. Darrel Herbst, then of the Department of Botany are: ageratum, andropogon, arundina, asclepias, brachiaria, carex, cassia, castilleja, cuphea, cyperus, desmodium, dicranopteris, emilia, erichtites, erigeron, lantana, lycopodium, melastoma, melinis, metrisideros, nephrolepis, pluchea, pteridium, rhychospora, rubus, saccolepis, spathoglottis, sphenomaris, stachytarpheta, tritenia, and vernonia.

Comparing these genera with the most relevant list of known endangered genera and their familial associations -- a tally of families, genera and species prepared by Charles Lamoureaux, Professor and Chairman, Department of Botany for the adjacent Hawaii Volcanoes National Park -- and with the comprehensive list of endangered, threatened and extinct species presented by the Secretary of the Smithsonian Institution to the Congress of the United States as House Document N. 94-51, 15 December 1974, it is concluded that endangered and threatened species of plants, if present at all at the well site, are extremely infrequent. Thus, the probability that well site operations will present this type of biohazard is deemed to be minimal.

With respect to the more general question of hazards to vegetation, it should be noted (1) that toxic emissions resulting from well operations are not likely to differ from those normal to natural vents and magmatic outgassing in Hawaii, and (2) that natural populations established by post-eruption colonization in areas of recent or current vulcanism are likely to be more resistant to toxic geothermal emissions than would be the case in non-volcanic locations.

5/ The mode of analysis is described in a report of the Hawaii Geothermal Project, Environmental Baseline Study for Geothermal Development in Puna, Hawaii, (Honolulu, September 1976).

(ii) Animals, particularly birds

The region of Puna around the geothermal well site, limited as it is in natural food sources for mammals, is not rich in fauna. The sugar cane fields to the west and the papaya farms to the east of the site support the rats which are found on all eight main islands of Hawaii. The mongoose is also well established locally. On the slopes of the mountains of the Big Island feral goats are at once quarry for hunters and problems for those who would preserve the ecosystem, but they do not come to this section of Puna.

The only valued animals which might be disturbed or conceivably threatened by geothermal development in the District are birds. There are on the Island of Hawaii several species of indigenous or endangered species, and it was necessary to study the area around the well site to ensure that none of these species were adversely affected by the geothermal exploration. Consequently, the environmental assessment was limited to birdlife which might feed or breed in the area of Puna near the well site.*

Field observations in February 1976 were concentrated on looking for the two species of endemic land birds which might be expected at the low elevation (approximately 600 feet above sea level) of the drill site. These are the Hawaiian hawk (Buteo solitarius), which is classified as "rare and endangered," and the Hawaiian short-eared owl, or pueo (Asio flammeus sandwichensis). No evidence of either was found -- perhaps because most of the native vegetation in the area has been replaced by exotic plants -- but of course it is possible that at times both species may occur in the general area. The hawk, in particular, is a wide-ranging species. This, however, is speculative, since no evidence was found.

* The assessment was made by Andrew J. Berger, Chairman of the Zoology Department, University of Hawaii at Manoa.

Nor is the area heavily populated with introduced birds. During the survey, only seven species were observed:

1. Spotted dove (Streptopelia c. chinensis)
2. Melodious laughing thrush (Garrulax canorus)
3. Japanese white-eye (Zosterops j. japonica)
4. Common myna (Acridotheres t. tristis)
5. House finch (Carpodacus mexicanus frontalis)
6. Spotted munia (Ricebird) (Lonchura punctulata)
7. Cardinal (Cardinalis cardinalis)

It is the considered opinion of the ornithologist who studied the area that the activities at the geothermal well site have had no adverse effect on any bird species inhabiting the area. Even an adverse effect on some of the introduced birds would not necessarily be detrimental, since some of these species, as the house finch and spotted munia, have been highly pestiferous in destroying crops on Hawaii, but no impact on any species was discerned.

In summary, with no evidence or past records of rare and endangered species inhabiting the area, and no indication of adverse effects on introduced species, it is concluded that any impact of geothermal drilling on the limited birdlife of the area adjacent to the site has not been significant. A judgment concerning the impact of geothermal development which might occur in other portions of Puna would of course require a localized study.

E. Archaeological Sites*

Puna has played a relatively insignificant role in the political history of Hawaii. During all of its known history, the District has produced

* Research on this section was done by William Bonk, Professor of Anthropology at the Hilo Campus of the University of Hawaii.

no great family or chief whose support was crucial for control over land contested by warring factions. Why it was that Puna never developed a political power base -- for lack of population or lack of adequate food sources to support a sufficiently strong army -- is not clear, but it is evident that in Polynesian times control over Puna was wielded by the bordering districts of Hilo and Ka'u.

Consequently, there are relatively few archaeological sites in Puna, say in comparison with the Kona coast or the northwest corner of the Island of Hawaii, and there is no major site of archaeological research interest in the District. What few sites exist are mostly along the coast, some distance from likely areas of geothermal development, which are along the rift zones inland.

The most extensive archaeological site complex in Puna is Kahuwaii Village at Makaukiu, above Cape Kumukahi, which is the easternmost projection of the Island. Around the cape to the south, near Isaac Hale Park, is Mahinaakaka heiau, in relatively good condition, except for the sea erosion of its eastern wall. Another ten miles down the coast are two additional heiaus and adjacent sites with petroglyphs, at Apua and Wahaula-Puuloa.

More petroglyphs are found near Kapoho, about three miles inland from Cape Kumukahi, and almost four miles from the exploratory geothermal well. These figures are unusual in that they are cut into the face of larger upright basaltic slabs, instead of the usual flat pahoehoe, and exhibit an "ear plug" seen at only a few other sites in Hawaii.

In the same general area, approximately two miles north of Kapoho, are the ruins of Kukii Heiau, repeatedly robbed of its stone -- for the building of the foundation walls of Iolani Palace in Honolulu in 1879, again for Queen Kapiolani's residence, and more recently for other construction.

With the exception of the petroglyphs at the Kapoho dome, none of the archaeological sites of Puna seem to be in the path of likely geothermal development in the District. If the Kapoho area is planned or authorized for development, protection of these petroglyphs should be assured before the development begins.[6/]

F. Aesthetic Considerations

Three qualities of developed geothermal fields must be considered for their impact on the aesthetic conditions of a geothermal area: they are rather noisy, they may emit sulfurous fumes, and they are likely to be covered with large structures. The noise caused by the escape of steam under pressure can be considerable, enough to make conversation difficult within a hundred yards downwind of a producing well, enough to be a nuisance to persons living within about a half-mile of the well -- unless the steam is directed to a generator or otherwise adequately muffled. With appropriate muffling devices, the sound level can be held down to tolerable levels, the tolerability being understood as a function of the number of persons affected and their sensitivity to noise, as well as a function of decibels. There is only one house within a half-mile of the present exploratory well site.

In any case, the noise levels of wells in any future geothermal field in Hawaii must be considered before development takes place, both for individual wells and, cumulatively, for a field. Given the expanse of little-used land in Puna, and developing technology for muffling the noise, there should be means for solving the noise problem in an environmentally acceptable manner. The mode of dealing with the problem on this project is discussed below.

The consideration of proximity of the well to population also applies to the sulfur smells (chiefly from H_2S) which may be released from geothermal

6/ A brief description of sites in Puna is appended to the Environmental Baseline Study for Geothermal Development in Puna, Hawaii, (Hawaii Geothermal Project, University of Hawaii, September 1976).

waters. HGP-A is regarded as relatively unsmelly by persons who have worked at the well -- no worse, for example, than the "rotten egg" odor encountered near fumaroles in the Volcanoes National Park. However, during the well testing in April 1977, complaints were made by a few local residents. These were referred to the chief sanitarian of the Department of Health on Hawaii. His report of 12 May 1977 accepted the findings of the Hawaii Geothermal Project biotoxicologists that emissions of H_2S and other elements posed no health hazard. That does not dispose of the matter of objectionable smell, a highly subjective matter. It will be minimized by the use of "scrubbers" in the generator equipment, discussed below in Part 4.

Questions of aesthetic appearance arise when a sizeable geothermal field is developed, since the field must have a network of steam-collecting pipes to supply the generating plant, the plant itself, and may require cooling towers to enhance the efficiency of the generator. (Under a vapor-turbine cycle mode of production, the towers may not be required and less noise-control equipment may be needed, but this technology is not yet available). However, this 4 - acre research and demonstration plant has a more limited aesthetic impact; modes of dealing with it are also discussed in Part 4.

3. SOCIOECONOMIC CONDITIONS IN PUNA

A. Population

Population movements in the Puna District during this second half of the twentieth century have roughly paralleled demographic changes of the entire County of Hawaii -- declining during the 1950's, remaining essentially stable in the '60's, then rising in the '70's so that the estimated 1977 level is somewhat above the population totals reported in the mid-century census. Projections for future changes are positive, both for the County and for the District.

TABLE 5

POPULATION TRENDS: HAWAII COUNTY, SOUTH HILO AND PUNA DISTRICT (1920-1990)

Year 1/	Hawaii County	South Hilo	Puna District
1920	64,895	23,828	7,282
1930	73,325	29,572	8,284
1940	73,276	32,588	7,733
1950	68,350	34,448	6,747
1960	61,332	31,553	5,030
1970	63,468	33,915	5,154
1976	76,600	39,600	7,800
	Estimates 2/		
1980	84-99,000	35-47,000	5,500-10,000
1990	115-137,000	37-55,000	8,400-13,000

1/ As of January 1 for 1920, April for (censuses of) 1930-1970, July 1 for 1976; unspecified for projected estimates.

2/ Range established by three series of projections: one made by Department of Planning and Economic Development, State of Hawaii in 1975, another by Belt, Collins and Associates, Honolulu, in 1973, and a third by Daly and Associates, Honolulu, in mid-1976. The minima shown for Hilo and Puna in 1980 and 1990 are obviously too low, barring some catastrophe.

The reduction in population for Puna -- as for Hawaii County as a whole -- between 1940 and 1960, is at least partly attributable to the mechanization of the sugar plantations, for long the chief employer on the Island and in the Puna District. South Hilo District, which demographically approximates the City of Hilo, showed a growth over most of this period, to include over half of the total Island population by 1970, a factor of significance to Puna, since the District increasingly has come to serve as a "bedroom" area for persons working in the city.

The lower end of the range of estimates of future population shown in Table 5 appear to be too low, at least for Hilo and Puna. They might prove to be true if the current depression of the sugar industry were to cause more layoffs, and if tourism and other industries which have been replacing sugar in the Island's economy were to level off or drop, but that basis of forecasting seems unduly pessimistic. A more likely and prudent assumption is that the growth of population experienced in the Puna District during the first half of this decade will continue, though perhaps at a decreased rate. A rise from the approximately 8,000 population now in the District to some 12,000 by 1990 seems to be a reasonable expectation.

During the last six years, a disproportionately large part of the population growth in Puna has occurred in the age bracket where people are most likely to be in the labor market, from ages 22 through 44. The changing pattern of age distribution has obvious significance for infrastructure needs of the District. The under-22 portion of the population (37% in 1976) particularly relates to projected demand for schools and play spaces, those between 22 and 64 for roads and police protection, those over 64 (13% in 1976) for public health services, recreation and mass transit facilities.

B. Housing

Judging from the limited data available, the quantity of housing available in Puna is relatively adequate. The basis of this observation is an inter-district comparison made by the Department of Research and Development of the County of Hawaii, shown in Table 6, which indicates that the ratio of population-to-housing units in Puna was second lowest among the nine districts of the Big Island and well below the county average.

TABLE 6

HOUSING UNITS AND POPULATION-TO-HOUSING UNIT RATIOS

COUNTY OF HAWAII, BY DISTRICTS

(1969, 1971 and 1973)

District	Housing Units as of: July 1969	December 1971	July 1973	Ratio of Population to Housing Units: July 1973
PUNA	1,777	2,049	2,561	2.42
South Hilo	9,654	10,925	12,218	3.15
North Hilo	590	539	543	2.83
Hamakua	1,510	1,575	1,597	2.85
North Kohala	952	970	982	3.10
South Kohala	849	947	1,138	2.48
North Kona	1,764	2,727	3,144	2.07
South Kona	1,041	1,134	1,164	3.09
Ka'u	1,046	1,100	1,171	2.97
County Totals	19,183	21,966	24,518	2.86

Source: Data Book 1975, County of Hawaii Department of Research and Development (Hilo, Hawaii, 1975), Table 74, p. 69.

Between 1973 and 1976, some 300 additional units, net of those razed or otherwise removed from the supply, were constructed in Puna, bringing the mid-1976 inventory of housing units in the District to approximately 2,900.[1/] This rate of increase in housing is greater than the growth rate in the District's population, so the ratio shown in Table 6 is even more favorable now.

And, if recency of construction is a reliable indicator of quality, the level of average quality should also be rising in Puna. In 1976, over one-third of the units were less than six years old; about half less than 16 years old. Only about 5 per cent were judged to be in poor condition structurally; less than 3 per cent lacked complete plumbing and kitchen facilities.[2/] (By way of comparison, the 1970 U.S. Census of Housing indicated that 5.6 per cent of all housing units in this state then lacked standard plumbing equipment.)[3/]

The supply of housing in Puna, then, seems reasonably adequate for the near term -- enough to support any modest increase in population which might accompany a limited economic expansion of the District. Since an even larger supply of housing lies in Hilo and along the roads connecting the county capital with Puna, all within a commuting range of less than one hour, it is difficult to see any likely shortage of housing if geothermal development were to occur.

However, the social support structure needed to serve an increasing population may present different demands, even if the supply of housing itself is adequate. New housing areas must be served by connecting road and perhaps public transportation; by water supply and sewage disposal systems; police, fire

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1/ Based on unpublished data in files of Hawaii County Department of Planning.

2/ According to the 1976 study of the Puna Development Plan prepared by Daly and Associates for the County of Hawaii.

3/ U.S. Census of Housing: 1970, Final Report HC (1) A13, reported in State of Hawaii Data Book: 1975, (Department of Planning and Economic Development), Table 271.

and public health facilities; schools and libraries; and other infrastructure which is most efficiently -- or at least customarily -- supplied by government. These are examined next.

C. Infrastructure

Public investment in the Puna District, as measured against the amenities taken for granted in more urban areas, cannot be said to be large. Within the District, rather immediately available to the Puna population of some 8,000 persons, are the following public facilities:

1. Water supply. Only around the more built-up areas in Kea'au and Pahoa, and in the beach area around Kaimu does the Hawaii County system provide a public supply. The distribution line serving the Pahoa community presently ends about a quarter mile from the HGP-A geothermal site, and would have to be extended to serve the extensive housing subdivisions nearby, if houses are constructed therein.

The few houses within a mile radius of HGP-A are supplied by rain catchment. After testing of the well earlier in 1977, a complaint was made that the rainwater supply of a house in the neighborhood had been contaminated. Investigation by the Hawaii Department of Health showed that the contamination was caused by the materials used on the roof and in the gutters, and had nothing to do with the testing of the well.

2. Sewage disposal. There is no public sewage disposal or treatment facility in Puna. Residences and other habitations must provide their own cesspools, septic tanks, or other methods of disposal. So will the Geothermal Project. If a sewer system has to be provided for the District at some time in the future, it will be a consequence of population growth and not of geothermal development.

3. <u>Roads and highways</u>. There are approximately 168 miles of county roads in Puna, most of the mileage being along Highway 11, which connects Kea'au at the northern end of the District with the Hawaii Volcanoes National Park; along Highway 13, which comes down from Kea'au to Pahoa in the center of the District and then continues to the black sand beaches on the southern coast of Puna; and along Highway 132, which goes from Pahoa, past the site of the geothermal project, through the papaya-growing area near Kapoho and then to Cape Kumukahi, the easternmost point of the Big Island. The coastal road, Number 137, damaged by an earthquake in 1975, connects with the Chain of Craters road winding up to the Volcanoes National Park, but travel along that touristically important route is interdicted by recent lava flows which cover about 10 miles of the highway.

The quality of the Puna roads varies considerably. Highways 11 and 13 are generally broad and well-paved, while Highway 132 is neither in places -- for example in stretches near the geothermal drill site where the highway is unpaved.

4. <u>Public transportation</u>. Along with other readily accessible areas of the Big Island, Puna is served by a public bus system, based in Hilo, which provides twice-daily service. There are no local taxis, shuttles or U-drive companies; these are concentrated in Hilo and its airport.

5. <u>Police and fire stations</u>. Within Puna District, there are two fire stations, at Kea'au and Pahoa; the Pahoa station has one fireman. There is a single police station, at Kea'au. Emergencies have to be serviced from Hilo.

6. <u>Public health facilities</u>. There are no hospitals or clinics in Puna District. The nearest hospitals are in Hilo, less than an hour's drive from most communities in the District.

7. Schools and libraries. There are four public, no private, schools in Puna: an elementary school at Keakealani, elementary-and-intermediate schools at Kea'au and Mountain View, and a kindergarten-through-high school at Pahoa, which is relatively central in the District. The single public library in Puna is also at Pahoa.

8. Recreational areas and facilities. The one category of public facilities with which Puna is well endowed is natural recreational areas. The Hawaiian Volcanoes National Park is readily available by car. So are the beach parks: Harry K. Brown, Isaac Hale, McKenzie, Kaimu Beach, the area around Queen's Bath. Tour buses may be noisesome at the black sand beaches of Kaimu and Kalapana, but seldom stop at the other beach parks. Less than a mile from the geothermal drill site is Lava Tree State Park, also not much disturbed by tourism.

In the population centers, there are five ball parks or general public parks, playgrounds at the Kea'au and Pahoa schools, and two gymnasiums open to the public. The one moviehouse in Puna is at Pahoa.

Conclusion. It would appear that any large increase in population for the Puna District would require expansion of the public water supply and provision of a sewage disposal system, if the increase were concentrated in urban-like neighborhoods, rather than spread out in detached farm areas. The big uncertainty in the development of the District is whether the presently demarcated but mostly empty subdivisions will be constructed on, or remain vacant. Geothermal development would relate to this question, but would seem to be of a second order of importance in determining the amount of population growth and, hence, the need for a public water and sewage system.

The pattern of growth, in an area as large as Puna, will obviously be of importance in determining the need for additional infrastructure investments.

Should that growth center near Pahoa and Kea'au, the population may perhaps be served at a level of service acceptable to them by the existing schools, fire and police stations, the parks and playgrounds. And it is this central area of Puna, along the rift zone, where geothermal development is most likely to occur. However, should areas zoned for subdivisions, but unimproved for want of a sufficient demand for these residential lots, be rezoned and developed for geothermally-related purposes, and should population growth move to areas more remote from Pahoa and Kea'au, there may be created a need for more social infrastructure investment, possibly including schools, playgrounds, libraries, fire and police stations, and access roads for the new housing area. In any case, it would seem that a larger population in Puna would require some local health facilities for at least emergency care before patients are transported to Hilo.

D. Economic circumstances; jobs

(i) Sugar. Historically, sugar has been the principal source of income in the Puna District. There are approximately 15,000 acres planted to sugar cane in Puna, producing between 50 and 60 thousand tons of sugar annually, or about one eighth of total sugar production on the Island of Hawaii. Acreage has not greatly changed in recent years, but mechanization of the plantation, here as throughout the State, greatly reduced employment in the local sugar industry--from almost 2,000 in 1940 to some 500 in 1960. Since that time, sugar employment in Puna has remained rather stable at about 500, including jobs in the Puna Sugar Company mill as well as in field operations.

Profitability of sugar operations has varied enormously in the past few years, with a temporary boom in sugar prices in the U.S. and world markets in 1973-75 being followed by a precipitous drop in 1975-76. There continues to be great uncertainty concerning the long-run prospects for sugar production throughout Hawaii.

(ii) Papaya. During the past decade other categories of agricultural output have become economically significant on Hawaii and particularly in Puna. The largest element of diversified agriculture locally is the growing of papayas for markets on the Mainland and abroad, as well as in the State. Almost 90 per cent of total papaya production in the State comes from Puna. According to the Hawaii State Department of Agriculture, between 1970 and 1976 the area planted to papayas in Puna increased from some 1,000 acres to approximately 1,800 acres, and the value of Puna papayas which were sold rose from $2 million to over $5 million. When that value is compared with the annual gross value of the Puna sugar crop (as unprocessed cane) -- which ranged from about $5 million in 1970 to some $24 million in the unprecedented boom year of 1974 but now again approximates the 1970 level -- it will be seen that papayas will challenge the primacy of sugar production in Puna unless sugar prices are reflated.

Patterns of employment in papaya are quite different from those in sugar. Due to mechanization and unionization, sugar employment is quite stable, with little seasonality and little turnover in jobs. The new papaya "industry," on the contrary, employs almost as many seasonal (late spring, early summer) workers as it does full-time, year-round workers. In the past year approximately 500 persons were employed in papaya growing, harvesting and processing in the Puna District, about the same total as for sugar, but representing only about half as many man-hours.

Despite some difficulty in retaining workers, many of whom are not unionized, and problems of getting dependable airline scheduling from Hilo to the West Coast and mid-continental markets, papaya production in Puna has been profitable and acreage planted to papaya is expected to continue increasing.

Since heat is used to process both fresh papaya and juices or purees made from the fruit, the papaya industry may be stimulated by the availability of geothermal water.

(iii) Other agriculture. The production of macadamia nuts, marketing guavas and raising anthuriums and orchids are also of economic significance in the Puna District. Great expectations for profits from macadamia nuts have been only modestly realized, at least in Puna, where the sales value of this high-priced delicacy fell from $1.7 million in 1970 to $0.8 million in 1973, according to the Hawaii State Department of Agriculture. A recovery in the following years regained the million dollar level, but market resistance to higher prices, increased foreign competition and continued problems in the now-mechanized harvesting process raised questions concerning further expansion of production and jobs in this specialty area. Peak season employment in Puna by C. Brewer and Co., based in Kea'au, is somewhat under 300, with even greater seasonality of work than for papaya.

Guava production, highly touted for the Big Island in the 1950's, has gained a modest base in Puna, where approximately 75 acres are cultivated for this tropical fruit, most of it to be processed into juice or preserves for bottling, canning or freezing. With improved efficiency in production and market promotion, an expansion of this base of operations may well be realized, but the impact on employment in Puna would be quite limited. A small number of self-employed persons work the orchards year-round and on a part-time basis; harvesting is done mostly by students and other casual workers. Establishment of a processing plant, should the level of production and the availability of geothermal water in Puna justify one commercially, would establish some year-round and seasonal jobs.

Oranges and other citrus fruit have been planted in Puna for commercial marketing but the enterprise has not been successful, largely because the fruit doesn't match the cosmetic standards established by the fruit industry of California and Florida, but also because of the heavy seasonality of production and the non-availability of facilities for making and freezing juice. Many of the orchards are now out of cultivation, but might be brought back if a local fruit-processing industry were to be stimulated by a geothermal water supply.

More successful has been the cultivation in Puna of tropical plants for the commercial market, particularly anthuriums and orchids. The proximity of the Hilo airport, which not only creates an immediate market in the local tourist trade but also ensures ready connection with markets in Honolulu, on the Mainland and in Japan, has greatly raised the demand for these horticultural specialities. Puna now supplies well over half of the total commercial production of anthuriums for the entire State, and approximately 90 per cent of Big Island production. . Despite large increases in output -- an approximate trebling of sales between 1964 and 1974 -- the "industry" has remained essentially one of family enterprise with part-time employment of workers outside the family. In 1975, it was estimated that about 330 people were employed in cultivating, picking, packing and wholesaling anthuriums in Puna, with a projected growth of 20 to 30 jobs per year as the marketing of this flower retains its healthy growth.[5/]

Orchid cultivation for the market in Puna is in a much earlier stage of development than is growing anthuriums. Several small orchid farms are in production in the District, but nurseries for more intensive and better controlled

5/ Estimates are by Daly and Associates, made in preparing their Puna Community Development Plan (1976).

cultivation have been established only recently. These, like the anthurium enterprises, are mostly family businesses, employing in all fewer than 50 people. Good growing conditions and a large potential market is expected to stimulate more production in Puna, but starting from such a small base the additions to employment and income to be derived from this activity must be expected to be small.

Table 7 presents a recent census of employment for Puna by industrial occupation. It is informative, but requires explanation to make it square with employment data presented above. Agricultural jobs, estimated for sugar, papaya, macadamia nuts, etc., would come to far more than the 718 shown in the table for "Agriculture." The table, using U.S. Census categories, puts jobs in sugar mills and food processing plants under its own rubrics, and so many of them in this instance may be under "Manufacturing," which helps explain the relatively large percentage under that classification.

The table does clearly show that Puna includes many people who have urban-related employment, as in the stores, offices and schools of Pahoa and Kea'au, those who commute to jobs in the hotels and shopping centers of Hilo, or who work in the filling stations along the highway. The unexpectedly large percentage under "Construction" and "Transportation, Communication, Utilities" may reflect the employment of people who live in Puna but commute to jobs in Hilo and adjacent areas.

There is no category in Table 7 for tourism. If there were, the number of positions reported would be very small, for Puna is an area which tourists traverse but spend little money in. There are no hotels, car rental agencies or touristic restaurants in the District. Tour buses and individual motorists do come down from Hilo in some numbers to see the black sand beaches and the painted church near Kalapana-Kaimu on the coast of Puna, and sometimes

TABLE 7

EMPLOYMENT OF PUNA RESIDENTS, BY INDUSTRY

INDUSTRY	NUMBER	PERCENTAGE DISTRIBUTION
Agriculture	718*	24.9%
Fishing, Hunting	12	0.4
Construction	502	17.4
Manufacturing	309	10.7
Transportation, Communications, Utilities	228	7.9
Retail/Wholesale Trade	548	19.0
Finance, Insurance, Real Estate	101	3.5
Service (including government)	467	16.2
Total	2,885	100.0%

* May exclude some employment in sugar, papaya and macadamia nut processing.

Source: Office of Economic Opportunity Census Update, County of Hawaii (1976), unpublished, as reported by Daly and Associates in Puna Community Development Plan.

they stop to see the steam rising from vents in the geothermal area (and, currently, to see the experimental geothermal well), but after looking around they head back to Hilo without having added to the gross product of Puna. The research facility which is the subject of this E.I.S. will attract additional sightseers. A more significant stimulus to tourism would be the construction of spa facilities in the area, accommodations which might particularly attract visitors from Japan, where geothermal spas are in great demand.

E. Summary

The Puna District is, by conventional American standards, relatively undeveloped. Within an hour's driving time from the capital and chief city of the county, and its international airport, Puna itself has only limited urban areas and urban facilities. Across much of its lava lands, housing subdivisions are laid out, but these yet contain few houses or construction crews. The chief sources of employment are agriculturally based, though many of its 8,000 population drive to jobs in Hilo.

There is a potential for development in the diverse agricultural activities of the District: papayas, guavas, macadamia nuts and tropical ornamental plants, as well as the historic mainstay of Puna's economy, sugar cane. The housing supply seems above average, both in quality and quantity, and should be able to accommodate the projected population increase at least for several years. Public services, however, will be strained by a continued increase in population, including the systems for delivering fresh water and removing wastes. There may well be a need for other infrastructure expenditures, as for schools, police and fire stations, a local health service facility, etc.

However, in itself, the proposed R & D facility will have only a negligible impact. A significant geothermal development in Puna would affect, and be affected by, all of the foregoing considerations. It might compete for land with some of the agricultural uses, though the areas most promising for drilling may be too active thermally for commercial agriculture. It would create jobs, both directly and indirectly, tending to relieve local unemployment, which has been high, and also attract people from other areas. Depending on the mode of geothermal development, it could diversify as well as enlarge the base for economic activity in Puna, as by stimulating diversified agriculture and also tourism, now only a negligible source of income to the population of the District.

4. MITIGATING ADVERSE IMPACT OF PROJECT; REVERSIBILITY

Because the Hawaii Geothermal Project is limited to a single production well in a small acreage located in a relatively remote area recently subjected to lava flows, the environmental impact is not great. However, as the ensuing discussion has revealed, some adverse effects must be taken into account and mitigated.

Disposal of effluents and waste. When in operation, the well will discharge from 60 to 100 gallons of liquid per minute, after the steam and hot water are run through the generator and condensor. If allowed to flow freely, the effluent would be a dangerous nuisance, because of its heat and the undissolved minerals in the fluid. To dispose of the effluent, it will be directed to settling basins within the fenced perimeter of the project area; there it will be absorbed in the highly porous cinder/lava surface and then percolate through the underlying strata into the geothermal reservoir below. As previously noted, there is no potable water lens below the well site -- if there is one adjacent, it is apparently blocked off by dikes of basalt rock at the southern boundary of the East Rift Zone.[1/] Because of the relatively large silica content of the geothermal water, the settling basins will be backhoed as they are coated over to restore the porosity of the surface and the silica deposits removed -- perhaps to be used as fill. The smaller quantities of sulfur cleaned out of the condensors from time to time may have enough economic value to be collected and sold; if not, they are easily disposed of as non-toxic waste products. (See pages 44-45).

Wastes of the persons working at the site will be disposed of by a cesspool or chemical system installed for that purpose.

Noise. The installation of a generator will itself reduce the noise level of the well, since the escaping steam will be channeled through turbines and a

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1/ This is the conclusion reached by Harold T. Stearns in his report on The Geothermal Well Field in the Puna District, Hawaii, dated April 4, 1977.

condensor, and this equipment in turn will be enclosed within the walls and roof of the generating station. The existing separator/muffler will continue to function; the overall design of the project is expected to reduce the noise level to a fraction of what has already been experienced at HGP-A so that the project will not be an auditory nuisance.

Smell. Tests by the Hawaii Geothermal Project have demonstrated that the gases from the well are not hazardous, but -- as with the effluents naturally vented within the Volcanoes National Park -- they do smell. The irritant particularly is hydrogen sulfide (H_2S), whose rotten egg odor is enjoyed by few people. The human nose is extremely sensitive to this chemical: the threshhold recognition level is approximately 0.0005 parts per million, whereas the health hazard threshold is 10.0 ppm.

To hold the discharge rate of H_2S down to a level that will not offend persons living near the project, a system of scrubbers will be installed with the generator. Several techniques are available: absorption by an oxidizing agent; absorption by activated charcoal; direct combustion or catalytic afterburning; condensation; etc. A scrubbing system will be selected from these alternatives and incorporated into the facility -- probably a catalytic process.

Visual impact. The most conspicuous element of the geothermal research and demonstration project to some persons will be one or two cooling towers, some 18 to 50 feet high (depending on the design chosen), necessary for efficient operation of the generator. The low building sheltering the wellhead generator and condensors will be screened by a wooden fence and by shrubbery, if plantings are feasible. The fence and cooling tower(s) will be of colors selected to best blend in with the surrounding terrain -- essentially dark gray lava with sparse covering of green plants and light gray-green lichens. The cooling tower(s) will be set back from the road to minimize the visual impact.

More conjectural and subjective would be the perceived effects of vapor which may be emitted from the condensors in the cooling tower(s). Depending on the ambient temperature and humidity, sometimes there may be vapor rising from the project. If this is a problem, it is one of aesthetics, not biology, since the droplets comprising the plume of vapor would be of rather pure water.

Parking will be off the adjacent Pohoiki Road so as not to present a problem to vehicular traffic on that county road, presently not heavily used.

Aesthetics, generally. How the research/demonstration project will be perceived in the Puna setting -- as an incongruous intrusion of technology in a relatively "natural" area, or as an interesting contrast to the lava forms -- will depend on the project design as well as the eye of the beholder. The HGP-A Development Group which will be administering the project has undertaken to use good design and landscaping to minimize intrusive impacts which people are likely to find objectionable, namely noise, smell and the appearance of structures and fencing around them. Should the project stimulate the development of a geothermal extraction field, the same care can keep the development from being a nuisance, but there is no gainsaying that the area will be changed.

Reversibility. The installation of a wellhead generator and provision of demonstration facilities is, as far as commitment of natural resources goes, essentially reversible. If required or warranted, the generator can be removed, the cooling tower and other equipment dismantled, the well sealed. The consequences would be economic, more than environmental, for a capped well is of no use whatsoever, and a used generator may cost more to move than it is worth. The lava land of Puna, stripped of the surface components of the project, would soon regain its natural state as the ambient ground cover once more took over, leaving only the covered wellhead to mark the site.

There is yet a question whether the extraction of geothermal fluid would leave the underground resource itself unchanged. One of the chief purposes of the project is to test the degree to which the reservoir is self-charging, so that fluids are replaced from natural sources as they are drawn up the well. If the answer is that there is no or minor recharge, then the resource is a depletable one, like oil, that may be replenished by nature only over extremely long periods of time. Should this be the answer, the rate of depletion would become a factor of concern to government planners, as well as to the agencies exploiting the field, in controlling the rate of development and utilization of the Kapoho geothermal field.

Danger from blowout. The operating hazard which is peculiar to a geothermal facility is the possibility of an uncontrolled release of the geothermal fluid, which is under high pressure. Consequently, a standard safety device on geothermal wells is a blowout preventer, a heavy-duty device which automatically chokes off the well should a failure occur. HGP-A will be operated with a blowout prevention system designed to withstand pressures up to 1,000 p.s.i., more than double the wellhead pressure at HGP-A recorded to date.

Sulfur sludge disposal. As indicated above, the mode of disposing of effluents from the well is presently expected to be a system of surface ponding. Should a study now underway show that it is feasible, with funds available, to drill a reinjection well, then a closed loop would be constructed whereby: (1) geothermal fluids would flow up the present well (HGP-A); (2) be directed through the wellhead generator and to other non-electrical applications at the project site; and (3) flow down the reinjection well back into the geothermal reservoir below. The closed-circuit system retains all elements in the geothermal fluids and so makes surface disposal of any waste products unnecessary.

Because it may not be feasible to use a reinjection well system, alternative planning is being made for removing most of the smelly hydrogen sulfide before the discharge water reaches the settling ponds, or basins, which would be used. Several H_2S abatement systems are available, and they are being evaluated before a selection is made. However, all of these devices yield sludge containing the sulfur "scrubbed" out, producing a problem of disposal. These alternative solutions are being considered:

1. Bury the non-toxic sludge at an approved landfill area; or
2. Purify the sludge into commercial sulfur and sell it on the market.

Either solution would be environmentally benign, so the choice would essentially be a matter of relative costs.

Environmental monitoring program. The grant agreement with the federal Department of Energy provides for monitoring the possible environmental effects of operating HGP-A on the air, water and soil in the vicinity of the well. The air and rainfall of the closest residential areas, as well as at test points further afield in the Puna District, will also be examined to establish further baseline data before the wellhead generator is put into service and the monitoring will continue as operations proceed.

5. SOCIAL BENEFITS AND COSTS OF GEOTHERMAL DEVELOPMENT

The environmental impact of a project limited to the present experimental geothermal well (HGP-A) is demonstrably trivial. HGP-A has already been tested repeatedly and the only untoward results have been some loud noise, which will be muffled, and some smell from the emission of H_2S, which will be scrubbed when the facility is installed. We therefore conclude that the installation of a small wellhead generator and conduct of a research and demonstration program on the Puna site should not have any profound effect on the environment.

More significant by far are the possible outcomes of a geothermal resource development stimulated by the project, a development requiring many wells and perhaps a much larger generating station. This part therefore considers the benefits and costs of geothermal development in Puna at large, and not merely the impact of HGP-A.

Any new power source can become the genie released from the bottle. Who could have written an adequate environmental impact statement about the first oil well in Pennsylvania, or about the first controlled use of nuclear energy at Chicago's Stagg Field? And yet, it is rational policy to require an assessment of potential new departures, such as geothermal energy, so that human foresight can be directed, within its short range, to the maximization of benefits from the projected development and to the avoidance of harm. Without pretending to envision the ultimate impact of geothermal development on the Island of Hawaii, it is possible to array the benefits and costs likely to be experienced over the first decades of developing geothermal resources, as at Puna.

A. Potential Social Benefits

(i) An Indigenous Energy Source. Hawaii is most vulnerable to the recurrence of an oil crisis, such as that which temporarily sobered the nation in 1974-75, and to continued increases in the price of petroleum. Every other state either has its own energy supplies (Alaska) or is connected to a regional power grid which can be fed at many points with oil or alternative fuels. Non-contiguous Hawaii presently has neither its own fuel supplies nor connections to depend on, should the importation of oil into this State be halted or become too expensive.

More than any other state, therefore, Hawaii has reason to seek energy sources within its own boundaries, and currently, in different stages of advance, searches are underway for means of tapping a variety of indigenous power sources. These include solar energy, wind energy, ocean thermal energy, energy from biomass conversion, and geothermal energy. While solar energy is already used on a small scale for heating domestic water supplies, the utilization of geothermal energy offers the technology most advanced for supplying other energy needs (outside the sugar industry, where the burning of bagasse is an efficient means of generating power for the plantation mills and the communities around them).

An indigenous power source, such as geothermal, would substitute for oil, which continues to rise in price. The potential gain is not only in holding down costs, but also in reducing economic uncertainty. After the 1974 oil embargo by the OPEC nations, all large users of oil-fed energy must take into account the possibility that without notice their power may be cut off, reduced or drastically increased in cost. The possibility pervades the economic climate, reducing incentives to invest in energy-intensive enterprises, stimulating the construction of oil-storage facilities and the substitution of less-energy-using methods for energy-intensive technology. These reactions may be patriotic and, given the uncertainty of supply, perfectly rational, but they do come at a cost. An indigenous energy source, if commercially feasible, could more effectively reduce dependence on imported oil, and at a lower economic price.

(ii) Economic growth; more jobs; more State revenues (eventually). In itself, geothermal power development need not be a sustaining source of either economic growth or job creation. Initially, as wells were being drilled and production facilities at the field were being built for a new geothermal facility, the construction industry would be stimulated. However, following the construction phase, if the only application of the geothermal resource were to be the generation of electricity, the economic significance of the development would be extremely limited. Since power stations are highly automated, only a few workers would be employed at a geothermally powered generating plant in Puna. They could benefit, and so could the owners and customers of Hawaii Electric Light Company, but in all likelihood, the gains would be too small to be visible in the economy of the State.

More significant economic and employment effects would depend on the applications made of geothermal power. In the event that large amounts of electricity were generated, and at a cost considerably below that from burning fuel oil, it is possible that new enterprises in number would be attracted to the Big Island, and that existing enterprises might be expanded sufficiently to create many new jobs. Alternatively -- or simultaneously -- firms which use geothermal water directly (such as fruit processing, wood and paper production) and other applications (such as therapeutic spas) might be clustered at the geothermal field, providing employment visibly connected with the new energy source.

Direct and indirect stimulation of employment would be particularly beneficial to Puna. Unemployment rates in the District during the past few years have averaged about 10 per cent, among the highest in the State. Unless the prices and profitability of the local sugar industry are reflated, the shrinkage of the plantations may be suddenly accelerated and in Puna -- and generally on the Island of Hawaii -- that would threaten a major source of jobs and income. A diversification of agriculture and agriculturally-based industry, stimulated by geothermal development, would be timely in the next decade.

Conceivably, the economic activity generated by geothermal development on the Island of Hawaii might benefit the public sector, as well as the private. In addition to royalties which the State would receive from the geothermal deposits which it has reserved, State and County tax revenues would be increased by a geothermal industry, as land values in and around geothermal fields rose and taxable buildings and other improvements were put into place; gross income stemming from the fields and from productive facilities powered by geothermal energy would be subject to the State's general excise and electricity sales to the public utility tax; profits and salaries from the geothermal "industry" would be taxed under Hawaii's corporate and personal net income taxes. By the operation of the multiplier, income streams created by the geothermal industry would feed into the overall economy of the State, generating additional tax revenues with the re-spending of each geothermal dollar.

However, during the remainder of the 20th century, net government income from geothermal development in Hawaii is not likely to be forthcoming. It is more probable that, at least for several years, the development of geothermal resources will require investment by the State government and its counties at a level which will exceed the tax revenues from this new source. Already, the State and County of Hawaii have granted $700,000 for the experimental well. Even if no additional financial support is given for drilling wells, it is likely that any significant economic development stimulated by geothermal exploitation will also stimulate outlays by the state or county governments. These may either be in direct support of geothermal utilization (such as access roads to the geothermal facility), or the infrastructure investment (water supply, waste removal systems) mentioned in Part 3 as being necessary to support population growth in the Puna District.

After geothermal development is well underway, the industry established and the infrastructure in place, the development should turn into a net revenue producer for the governments which have fostered it. That, however, is a long-term prospect, one for the Twenty-first Century.

(iii) Decongestion of population. The creation of jobs in an expansion of the Big Island's economy powered by a new energy source could help implement the announced policy of the State administration to check the concentration of population in and around Honolulu. Despite the enunciation of this policy at the beginning of this decade, Oahu continues to hold more than four-fifths of the population of the State, with no viable program for holding back increased congestion in the capital city.

It is unlikely that development of a geothermal resource in itself, unless the field were unexpectedly huge, would provide such massive employment as to cause the transfer of many people to the Big Island. And it may well be that the Big Island would not welcome a large in-migration. However, a major geothermal development could fuel a general economic growth -- in agriculture, industry and tourism -- which the authorities of Hawaii County would either welcome or be unable to control. How much of this hypothesized growth would be reckoned a plus for the Island of Hawaii is a question of values, but, should it occur, it would increase the gross State product and, perhaps, would marginally reduce crowding on Oahu.

(iv) Environmental Effects: Geothermal versus Other Energy Sources. It is not likely that geothermal development would improve the physical environment. In Part 2, it was concluded that drilling HGP-A has not had much impact, and that the limited environmental effects of installing a generator and other facilities to test the geothermal resource could be minimized by muffling, scrubbing, landscaping, etc. However, a development stimulated by the R & D project would be of much greater environmental significance, and there may well be people in the community who would prefer to leave Puna, and other potential development sites, unchanged, or not changed in this way.

Presented with a choice between geothermal development and allowing no change in the environment, many persons might prefer the status quo. Realistically, however, that is not the choice which will confront the people of Hawaii. Given the strong probability that oil resources will become extremely scarce by the end of this century, it is most likely that some energy source will displace oil, or that only grades of oil with high sulfur content will be available at an affordable price.

If the alternatives available for Hawaii's future energy needs should be limited to what is now technically and economically feasible, the choice would be between more polluting oil, coal, nuclear power, and geothermal energy. With these alternatives in view, a rational choice on environmental grounds could well go to geothermal energy, which is much less polluting than coal or other hydrocarbons, and less dangerous than nuclear power. In this sense, as one of the least polluting power sources, geothermal resource development would be a positive factor for preserving the environmental quality of Hawaii.[1/]

1/ In the judgment of persons serving on the investigatory groups which prepared the report on Alternative Energy Sources for Hawaii for the State Advisory Task Force on Energy Policy (University of Hawaii and Department of Planning and Economic Development, 1975), geothermal energy was preferable with respect to environmental impact over land-based use of coal, specifically in their relative impact on water and air and in the discharge of solid wastes. An ocean-based coal power station or the burning of liquified coal rated slightly better than geothermal energy in the opinion of the three persons serving on the task force on the environment, while in the opinion of some 50 people who served on the alternative energy source task forces, geothermal power was preferable to coal, however utilized. (Op. cit., pp. K-3 and 4).

B. Potential social costs and their minimization

The opportunity costs of using geothermal resources will probably be relatively low. The lands around the rift zones of Kilauea which seemingly overlay the hot water are frequently picturesque but seldom of much economic value. Only a small portion of these lands are in cultivation, and use of the terrain for housing is limited by many factors, not least of which is the seismic activity of the area: it was subjected to an earthquake of 7.2 magnitude on the Richter scale as recently as November 1975. Lands utilized in a geothermal field within Puna are not likely to be taken from any highly productive alternative use.

If geothermal wells penetrated an extensive Ghyben-Herzberg lens, then there would be danger of paying a high cost in endangering the local groundwater supply. However, as stated above in Part 2, the experience from well-drilling in the Puna area does not seem to indicate the existence of a fresh water lens of potable quality. For such fresh water reservoirs as may be encountered, appropriate well-casing programs and well maintenance should be able to guard against polluting groundwater otherwise usable for household needs or irrigation.

Other environmental pollution, which may add to the social costs of geothermal development, can be held to a minimum by appropriate safeguards. At the HGP-A well, mufflers are used to reduce the noise of steam issuing from the wells, landscaping will limit the visual intrusion, constant monitoring ensures that noxious gases or particulates do not exceed safe maxima. In a future production field, effluents can be reinjected into the reservoir after passage through a closed system, to minimize the environmental impact of using the geothermal resource.2/

2/ A framework for environmental oversight is provided in the regulations on geothermal drilling which were in the process of being adopted by the Hawaii Department of Land and Natural Resources at the time of this writing.

More likely to be an obstacle to geothermal development than the costs of environmental protection is obtaining the investment capital necessary for creating a production field and application of the resource to productive usages. The magnitude of such investment is considerable: it will cost tens of millions just to create a medium-size electric power facility. How to raise such funds for an investment as inherently risky as drilling wells into hidden subterranean reservoirs will present the first economic barrier to geothermal exploitation. If grants or low-interest loans can be obtained from the national government (the Department of Energy has a loan program just getting well under-way), the drain upon Hawaii-based capital -- and hence the opportunity costs of the investment to the Hawaii economy -- can be kept down. Attracting investment capital from the mainland U.S. or abroad could have a similar effect in terms of opportunity costs, but would raise questions of out-of-state control over the geothermal development and increase the out-of-state flow of funds generated by a successful development.

A kind of economic cost which is unique to resources tapped by wells -- that is oil, gas, water and geothermal resources -- is waste through competitive exploitation. Since the reservoirs holding these subterranean resources frequently underlie lands held by more than one party, there is a temptation for competing enterprises to drill as many wells, either straight down, or slanted under adja-cent properties, as will maximize their share of the output. However, such drill-ing programs may not maximize total output from the field. On the contrary, by puncturing the reservoir excessively, they may cause a loss of pressure which leaves below the surface, unrecoverable except with costly techniques, some of the resource which a more efficient drilling program could have tapped with fewer wells.

By its policies and regulation, the State of Hawaii can restrain inefficient modes of exploiting a geothermal field. The proposed rules of the Hawaii State Department of Land and Natural Resources relating to geothermal wells allow for unit, or cooperative, development of a geothermal pool by several drillers, but do not require this approach to resource conservation. It may be that the limited facilities and expertise for deep drilling in Hawaii will make for a monopoly in development of the resource, but if not, the losses from uneconomical beggar-thy-neighbor exploitation could be significant.

C. Summary

Geothermal energy offers potential benefits to Hawaii, which, given this state's virtually complete dependence on oil, are of importance to its economy. Reducing this utter dependence by substituting indigenous geothermal water for imported petroleum to fuel the generation of electricity would not only reduce cash outflows (and perhaps hold down the price of electricity) but would lower the present uncertainty of continued reliance on oil from overseas suppliers.

However, a geothermal development limited to a small or medium size (say 35 to 50 MW) electric generating plant, would not have much impact on the Hawaii economy. A substantial economic impact might result from a generating facility large enough to bring down the cost of electricity and stimulate many industrial applications on the Big Island (or, when technological breakthroughs permit, the export of energy to industrial markets off the Island). Multiple use of even a limited geothermal resource might create in agriculture, industry and tourism a significant number of jobs, not to be expected from an automated generating plant itself.

An increase in job opportunities on Hawaii would help the State to implement its announced policy of minimizing further congestion of population in and around Honolulu. Geothermal development and associated economic growth in Puna would require the construction of water supply and waste disposal systems, plus other infrastructure, to serve a larger population. Such public costs would offset, perhaps exceed, additional tax revenues generated by an economic expansion based on geothermal production. Only after many years is it to be expected that the royalties received on State mineral leases, plus the taxes on geothermally-stimulated business, would exceed the cost to the government of preparing the way for and perhaps participating in the development of the new resource.

6. ALTERNATIVES TO PROPOSED ACTIONS

The question of alternatives to the proposed research and demonstration project for geothermal energy may be construed in two ways. The first is: "What alternatives are there to this new energy source?" The answer to this question is expanding the use of petroleum, on which Hawaii is now so heavily dependent, or seeking other substitutes for petroleum. Those substitutes which seem technically possible for Hawaii include solar, ocean thermal, wind and biomass-derived energy, among indigenous sources, and coal and nuclear energy, among the non-indigenous sources.

On environmental as well as economic grounds, it seems preferable to secure indigenous energy sources, and such is the policy of the State of Hawaii. Among the indigenous sources, geothermal power is at a stage of development most advanced for the production of commercial and industrial power, as contrasted with the application of solar energy for heating domestic water supplies, a technology already in use for that limited purpose. Geothermal energy is not considered an alternative to ocean thermal, wind or biomass energy, in the sense of being a complete substitute. Rather, these are complementary modes of energy production which together may significantly reduce Hawaii's dependence on imported oil.

The second construction of the question is: "What alternative sites have been considered for this geothermal research and development project?" Before the well, HGP-A, was drilled, University of Hawaii geophysicists studied the Big Island over the course of two years.[1/] They selected the drill site as that most likely to tap a geothermal reservoir within the areas open for such drilling. (Locations within the Hawaii Volcanoes National Park and built-up areas

1/ Several techniques were used to locate the site where there was the highest probability of tapping a geothermal reservoir. These included infrared were excluded from consideration as being unavailable). The success of that drilling now limits the R & D project to the area of the well, for it would be costly, inefficient and environmentally disruptive to pipe the steam and hot water any distance from HGP-A.[2/]

In summary, the alternatives to the proposed action are to abandon geothermal testing or to do it at a place removed from the present well. Abandonment would slow down or possibly end for the time being the development on the Big Island of geothermal energy. An immediate consequence would be the construction of another oil-burning generating plant by the Hawaii Electric Light Company. A long-range consequence would be to increase the likelihood of bringing in coal-burning or nuclear power stations by the end of the century, if oil supplies prove to be as scarce and expensive by that time as is widely predicted.

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photography from an airplane to find hot zones, geoelectrical surveys to find places of high conductivity which may be associated with hot subsurface liquids, and microearthquake and microseismic surveys to identify possible geothermal activity at depth. The most promising survey results converged on the area in the immediate vicinity of HGP-A. For a listing of research publications reporting the results of these and other investigations preceding the drilling, see Bibliography at B-1, below.

2/ The pipes necessary to bring the hot fluid from the wellhead to a research/demonstration facility located away from the well would necessarily intrude on more space; the heat lost in piping the fluid would reduce the efficiency of the generator.

7. CONTROLLING FUTURE GEOTHERMAL DEVELOPMENT

The research and demonstration project which is the subject of this E.I.S. will in itself have minor environmental effects, but if it is successful in its purpose of stimulating the development of a new energy source, the long-run environmental consequences would be much more significant. The State and county governments are therefore concerned over what controls they may have on a nascent geothermal "industry": are there adequate mechanisms available to them to check unwanted directions or degrees of its development?

The adequacy of any governmental controls obviously depends on the alacrity and skill with which they are applied, but it is evident that there is no dirth of control points over geothermal development.

A. <u>Controlling Geothermal Uses of Land</u>

<u>Land Use Law</u> (Chapter 205, Part I, HRS)

Most of the lands around the project are classified as "agricultural." To use such land for drilling or producing from geothermal wells, the owner or operator must obtain a special use permit from the County Planning Commission, subject to approval by the State Land Use Commission. Should either level of government wish to direct or stop a given geothermal project, it has the means at hand in the special use permit process -- subject to appeal to the courts if permission is unreasonably withheld, but with a burden on the applicant to show the unreasonableness of government action.

If geothermal development is proposed for watersheds, forests, parks, wilderness areas or other lands classified as "conservation," permission must be granted by the State Department of Land and Natural Resources, which has control over areas so classified. The subzone called "General Use" admits uses "not detrimental to a multiple use conservation concept," which might include geothermal wells, but the DL&NR would have to be convinced.

B. Environmental Controls

State Environmental Quality Control Law (Chapter 343, HRS)

Under the statute, any project which will probably have "significant effects" proposed for conservation lands, within a shoreline setback area, on a registered historic site, one which requires an amendment to County general plans, or any project using State or County lands or funds, must submit and obtain approval by the Environmental Quality Commission of an environmental impact statement. Notice must be given to public agencies, as well as interested private parties, who may voice their objection to any aspect of the project.

National Environmental Quality Control Law (PL 91-190)

If federal funds are used on a project, it may also be subject to a federal E.I.S. Such was the case with the drilling of HGP-A, since much of the funds were provided by the National Science Foundation and then the Energy Research and Development Administration, and so it is now with this project, since funding will come from the Department of Energy. It is not clear if a private geothermal enterprise, using loan funds guaranteed by the federal government, would be so subject.

C. Controlling Access to Geothermal Resources

State and County Lands. The State of Hawaii holds title to large parcels of land -- almost 40 per cent of the area of Hawaii County, for example, -- and as landowner the government can control access to geothermal reservoirs underlying its holdings. The County of Hawaii itself owns land, on a much smaller scale. It has title to two parcels in the geothermal area of Puna.

State mineral rights; Regulation. Since the Great Mahele, the government of Hawaii has reserved to itself rights to minerals beneath many parcels granted to private owners, and by Act 241 of the 1974 Hawaii Legislature, geothermal resources are defined as mineral.

Under Chapter 182, HRS, ("Reservation and Disposition of Government Mineral Rights"), the Department of Land and Natural Resources may issue leases to drill geothermal wells on private lands where mineral rights are reserved, as well as on state-owned lands. Conditions for getting and using geothermal leases are set down in rules and regulations relating to geothermal operations presently being considered for adoption by the Board of Land and Natural Resources. The rules are concerned with environmental safeguards and protecting the productive capacity of geothermal reservoirs, as well as safety and economic regulation.

D. Other Government Controls

General Plans. The 1977 Hawaii State General Plan encourages the development of indigenous energy sources, but as yet has no specific development plan or criteria for geothermal energy. Provisions relating to geothermal development in the State General Plan and in the plan of the County of Hawaii could set objectives and boundary conditions which would be helpful to the Department of Land and Natural Resources, the State Land Use Commission, the County Planning Commission, and other public agencies which have to respond to initiatives for geothermal development.

Public Finance Methods. The pace, if not the direction, of geothermal development can be influenced by discretionary fiscal actions available to the State government. It may accelerate development by setting at low levels the royalty payments it collects on State-owned geothermal deposits; by giving special tax considerations (especially under the property, net income and general excise taxes) to geothermal companies; by providing access roads, water supply, sewage disposal and other infrastructure investment in support of new geothermal fields. Such indirect -- and conceivably direct -- subsidies could be conditioned upon the State's satisfaction with private development plans. Tax incentives, however, must be offered to all comers and so are a less flexible mode of control over development of a new natural resource.

E. Congruence with Government Plans

The joint sponsorship of the geothermal project by the State and County of Hawaii bespeaks its fit into the plans and objectives of both governments. The new General Plan of the State, drafted by the executive and now being submitted to the Hawaii State Legislature, singles out the development of indigenous energy sources, including geothermal power, as an important State objective for the last part of the 20th Century. The General Plan of the County of Hawaii, adopted in 1971, makes no mention of the then-undiscovered new energy source, but there is no conflict between the courses of action recommended in the Plan for Puna -- developing agriculture and related industrial activities -- and the geothermal research/demonstration facility at HGP-A. More positively, the facility is a means of implementing the goal of greater self-sufficiency in energy supply which the County of Hawaii seems to be adopting in fact, though not yet by official proclamation.

8. LIST OF NECESSARY APPROVALS

Construction of a research/demonstration facility for geothermal energy at the HGP-A well site requires the following governmental approvals or scrutiny:

1. The Federal Department of Energy must approve the project, since it is financing most of the costs, and will prepare its own environmental impact statement to comply with the National Environmental Quality Control Law.

2. The Planning Commission of the County of Hawaii has been asked to grant a special use permit, since the land involved is zoned agricultural. The permit is subject to approval by the State Land Use Commission.

3. Construction of the structure comprising the facility will require approval by the Building Department of the Hawaii County Department of Public Works before the necessary building permit is issued.

4. Operation of the well will be subject to the rules and regulations governing geothermal well operations, now under consideration by the Board of Land and Natural Resources.

5. The State Department of Public Health is responsible for checking on air and water pollution which might be caused by the project, not only from the operation of the geothermal well, but from sewage disposal on the site; public health regulations must be met.

9. AGENCIES AND ORGANIZATIONS CONSULTED IN PREPARATION OF E.I.S.

A. Federal

U.S. Department of Energy (formerly Energy Research and Development Administration)

B. State of Hawaii

Department of Planning and Economic Development

Department of Land and Natural Resources

Department of Health

Department of the Attorney General

Office of Environmental Quality Control

C. University of Hawaii

College of Engineering

Environmental Center

Water Resources Research Center

College of Arts & Sciences --

Department of Botanical Sciences
Department of Microbiology
Department of Zoology

College of Tropical Agriculture

School of Public Health

Hilo College

D. Public Utilities

Hawaiian Electric Company

Hawaii Electric Light Company

E. Private

Chamber of Commerce of Hawaii

Congress of the Hawaiian People

Life of the Land

10. COMMENTS AND RESPONSES MADE CONCERNING THE E. I. S.

The following letters were received in response to the E. I. S. Preparation Notice and to the first draft of the E. I. S. Many other comments and suggestions, communicated by memoranda within the Department of Planning and Economic Development, were responded to by revisions in the text and are gratefully acknowledged by the author.

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

W. Y. THOMPSON, Chairman
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
CONVEYANCES
FISH AND GAME
FORESTRY
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

September 23, 1977

DIRECTOR'S OFFICE
SEP 27 1977
DPED

Honorable Hideto Kono
Department of Planning and
Economic Development
P. O. Box 2359
Honolulu, HI 96804

Dear Sir:

We are pleased to learn of progress being made on HGP-A.

The EIS preparation notice appears adequate except:

1. There is lack of details about the visual impact of the cooling tower.

2. No mention is made if the project will add to ambient levels of mercury.

Very truly yours,

W. Y. Thompson

W. Y. THOMPSON
Chairman of the Board

cc: DOWALD

University of Hawaii at Manoa

Hawaii Geothermal Project

MEMORANDUM November 22, 1977

Mr. W. Y. Thompson, Chairman
Board of Land & Natural Resources
Department of Land and Natural Resources
P. O. Box 621
Honolulu, HI 96809

Re: E.I.S. for Geothermal Research Facility at Puna

Dear Mr. Thompson:

Mr. Kono referred to me your letter of September 23, 1977, commenting on the E.I.S. preparation notice so that the E.I.S. itself would have the benefit of the points you raised. May I reply to each of them.

1. Information about the probable height of the cooling tower is included in the E.I.S., as well as noting the concern of the project to minimize aesthetic intrusion, within limits given by technological requirements for the cooling system. The height and bulk of the tower (or possibly towers) cannot be specified until the unit is designed.

2. The E.I.S. now specifies, on the continuing observations of Professors Stanford and Barbara Siegel, that the geothermal well has not measurably added to the ambient level of mercury in that area of Puna, and that the level is essentially set by natural emissions along the rift zone -- particularly, in recent months, by the Heiheihulu cone. In the words of Mr. Siegel: "Measurements carried out in July-September, 1977, show the presence not only of air mercury, but also of SO_2 and H_2SO_4 at HGP-A, although the well itself had been shut down since May. The presence of these toxic gases can only be ascribed to natural area contamination, not introduction from the well itself."

I hope that this reply adequately addresses your concerns.

Sincerely,

Robert M. Kamins

ROBERT M. KAMINS
Consultant

RMK:ny

cc: Department of Planning and Economic Development

COUNTY OF HAWAII

PLANNING DEPARTMENT

25 AUPUNI STREET • HILO, HAWAII 96720

HERBERT T. MATAYOSHI
Mayor

SIDNEY M. FUKE
Director

DUANE KANUHA
Deputy Director

SEP 12 1977

September 7, 1977

Mr. Hideto Kono, Director
Department of Planning &
Economic Development
P.O. Box 2359
Honolulu, HI 96804

Dear Mr. Kono:

Geothermal Research Facility Project
Environmental Impact Statement (EIS)
Preparation Notice
TMK: 1-4-01:2 por.

Thank you for the opportunity to review the above EIS Preparation Notice. We have the following comments to offer:

1. The EIS should discuss the State Land Use Classification and County Zoning. This discussion should also include the need to obtain a Special Permit from the State Land Use Commission.

2. The Environmental Setting section should include the data and discussion presented by the HGP research team's publications. Much of the data has been quantified in these reports.

3. The chief impacts presented by this Preparation Notice are visual, H_2S and noise. As there are existing geothermal steam supplied electrical generating plants in other parts of the world, we should perhaps look to these plants for methods in coping with these as well as other "problems". The EIS should present such discussion.

4. The discussion of Alternative Sites appears to limit the placement of the demonstration facility to the well site. The Geysers development in California operates without such a limitation. More discussion in this area appears to be required.

We hope these comments will aid you in preparing the EIS. We look forward to reviewing the completed document.

Sincerely,

SIDNEY FUKE
Director

RN:mmk

cc: Mayor
Chief Engineer
R & D

University of Hawaii at Manoa

Hawaii Geothermal Project

MEMORANDUM November 22, 1977

Mr. Sidney M. Fuke, Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, HI 96720

Re: E.I.S. for Geothermal Research Facility at Puna

Dear Mr. Fuke:

Mr. Kono has referred to me your letter of September 7, 1977, commenting on the E.I.S. preparation notice for the Geothermal Research and Development Facility in Puna, so that I might have the benefit of what you have pointed out in writing the E.I.S. proper. I respond in the order of your comments.

1. The controls over geothermal development placed by State land use classification and County zoning are discussed in Part 7 of the E.I.S.

2. The portion of the E.I.S. dealing with the environmental setting does indeed include data and discussion from the Hawaii Geothermal Project's earlier research. Both baseline data (showing conditions of the air, groundwater, soil, etc.) for the period before HGP-A was drilled and tested, and post-testing observations are included in Parts 2 and 3.

3. The persons directing and preparing the specifications for the new facility are familiar with the experience at The Geysers and other major geothermal fields in dealing with visual, noise and odor problems and are utilizing this experience to minimize problems at Kapoho. Some of the resulting detail -- for example, in the specifications for scrubbers to remove most of the H_2S -- is presented in the text and appendix of the E.I.S., but it was not feasible, in what is essentially a non-technical report, to discuss impact-abatement techniques in great detail. However, if you would like additional detail, I will ask the project engineers to provide it.

4. Considerations of both efficiency and environmental protection dictated locating the research/demonstration unit on the well site. Were it placed at any distance, conveyor pipes would be required to bring the hot fluid to the generator and associated facilities; the cost of a long piping is a reduction in temperature which directly affects the productivity of the generator. It was also taken to be an advantage that piping, and therefore the area of land surface affected by the project, would be kept to a minimum by constructing the research/demonstration unit at the wellhead itself.

Should a geothermal field develop as a result of this testing, then these considerations would vanish or become much less important. There would be collecting pipes running across the field, and generating stations and other utilization points could be located according to criteria other than proximity. However, for the single-well research/demonstration facility, proximity seems to be the best criterion for siting.

Thank you for your helpful comments.

Sincerely,

Robert Kamins

ROBERT M. KAMINS
Consultant

RMK:ny

cc: Department of Planning and Economic Development

HERBERT T. MATAYOSHI, MAYOR
CLARENCE W. GARCIA, DIRECTOR

DEPARTMENT OF RESEARCH AND DEVELOPMENT 148

COUNTY OF HAWAII • 25 AUPUNI STREET • HILO, HAWAII 96720 • TELEPHONE (808) 961-8366

SEP 15 1977

September 14, 1977

Mr. Hideto Kono, Director
Department of Planning and
Economic Development
P. O. Box 2359
Honolulu, HI 96804

ENVIRONMENTAL IMPACT STATEMENT PREPARATION NOTICE FOR THE GEOTHERMAL RESEARCH FACILITY PROJECT AT PUNA, HAWAII

Thank you for the opportunity to review the abovementioned subject matter. We share the enthusiasm of DPED and the University as to the potential positive benefits of utilizing HGP-A for practical and scientific power production.

We await the submission of the EIS and will reserve comments until that time.

CLARENCE W. GARCIA
DIRECTOR

MI:ef

University of Hawaii at Manoa

Hawaii Geothermal Project

MEMORANDUM

November 22, 1977

Clarence W. Garcia, Director
Department of Research and Development
County of Hawaii
25 Aupuni Street,
Hilo, HI 96720

Re: E.I.S. for Geothermal Research Facility at Puna

Dear Mr. Garcia:

Since the E.I.S. process includes acknowledging and taking into account responses made to the preparation notice, Mr. Kono referred to me, as well as to his staff, your letter of September 14, 1977.

I trust that the E.I.S. will meet with your satisfaction. All who have worked on the project have been heartened by the enthusiasm of the County of Hawaii for utilizing the new resource represented by geothermal reservoirs.

With best regards,

Bob Kamins

ROBERT M. KAMINS
Consultant

RMK:ny

cc: Department of Planning and Economic Development

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
HONOLULU, HAWAII 96801

GEORGE A. L. YUEN
DIRECTOR OF HEALTH
Audrey W. Mertz, M.D., M.P.H.
Deputy Director of Health
Henry N. Thompson, M.A.
Deputy Director of Health
James S. Kumagai, Ph.D., P.E.
Deputy Director of Health

DIRECTOR'S OFFICE
OCT 12 1977
DPED

October 7, 1977

In reply, please refer to:
File: EPHS - SS

Mr. Hideto Kono, Director
Department of Planning and
Economic Development
P. O. Box 2359
Honolulu, Hawaii 96804

Dear Mr. Kono:

Subject: Request for Comments on Proposed Environmental Impact Statement (EIS) for Geothermal Research Facility Project at Puna, Hawaii

Thank you for allowing us to review and comment on the subject proposed EIS.

Although we are aware of the fact that H_2S emissions will be minimized by the use of scrubbers, we recommend that public informational meetings be held to inform the residents of the affected community prior to any construction. In particular, please be sure to meet with the presidents of the Leilani and Nanawale Estates community associations.

We realize that the statements are general in nature due to preliminary plans being the sole source of discussion. We, therefore, reserve the right to impose future environmental restrictions on the project at the time final plans are submitted to this office for review.

Sincerely,

JAMES S. KUMAGAI, Ph.D.
Deputy Director for
Environmental Health

cc: DHO, Hawaii

University of Hawaii at Manoa

Hawaii Geothermal Project

MEMORANDUM

November 22, 1977

James S. Kumagai, Ph.D.
Deputy Director for Environmental Health
Department of Health
P. O. Box 3378
Honolulu, HI 96801

Re: Your letter of October 7, 1977
Comments on Proposed E.I.S. for Geothermal Research Facility project at Puna, Hawaii

Dear Dr. Kumagai:

Since responses to the E.I.S. rejoinders must be included in the final Environmental Impact Statement, Mr. Kono has referred your letter to me, as author of the E.I.S., as well as to his staff.

They have, I am confident, taken note of your suggestion that residents of the affected communities be informed prior to any construction. By inclusion of your letter in the E.I.S., you are on record as reserving the right to impose future environmental restrictions on the project when final plans are submitted to your office for review.

Sincerely,

Robert M. Kamins

ROBERT M. KAMINS
Consultant

RMK:ny

cc: Department of Planning and Economic Development

4-3 Geothermal
NV/R

HAWAIIAN ELECTRIC COMPANY, INC.
Box 2750 / Honolulu, Hawaii / 96803

September 6, 1977

RICHARD E. BELL
MANAGER, ENVIRONMENTAL DEPARTMENT

DIRECTOR'S OFFICE
SEP 8 1977
DPED

Mr. Hideto Kono, Director
State of Hawaii
Department of Planning and
Economic Development
P. O. Box 2359
Honolulu, Hawaii 96804

Dear Mr. Kono:

Subject: EIS Preparation Notice for the Geothermal Research Facility

This is in response to your request of August 30, 1977 for comments on subject document. The paragraph number below refer to paragraph numbers in the Preparation Notice.

Par. 3. HELCO intends to purchase up to 2 megawatts of power from the facility if a mutually agreeable price can be established.

HELCO intends to extend a transmission line to the generator after a mutually agreeable price for the power has been established.

Par. 6. The project will also establish whether or not a reliable, base load generator can be located satisfactorily in a volcanic rift zone.

Par. 8c. Since the area initially was free of man-made structures, any structure will cause a visual impact. It seems questionable that the cooling tower will cause the chief visual impact. At night, for example, a single 60 watt light will be far more noticeable. An essential question relates to whether the visual impact is positive or negative -- or in this case, is any visual intrusion negative.

?

Par. 10a. The facility now generally produces no noise. Thus, to maintain that when fully developed it will cause no greater noise than now is inaccurate. It seems reasonable that noise will definitely be greater in the area than before the project started. No basis if given, therefore, for the assertion that noise will not be a problem. The point here is that the adverse impact of noise will be offset by advantages of the project -- if this is true, of course.

Par. 10b. Whether or not H_2S can be reduced below the nuisance level is problematical.

Par. 10c. Fencing will improve the appearance of the facility and thus may increase the positive visual impact. That is, visual impact can be either, or both, negative or positive.

Sincerely yours,

[signature]

REB:cm

University of Hawaii at Manoa

Hawaii Geothermal Project

MEMORANDUM November 22, 1977

Mr. Richard E. Bell, Manager
Environmental Department
Hawaiian Electric Company, Inc.
Box 2750
Honolulu, HI 96803

Dear Mr. Bell:

Your letter of September 6, 1977, to Mr. Kono commenting on the E.I.S. preparation notice for the Hawaii Geothermal Research Facility project was referred to me as I am preparing the Statement. I reply to your comments in their order.

1. What you have said about HELCO intentions of power purchase has been incorporated in the E.I.S.

2. The problem of working in a volcanic rift zone has been stated; thank you for making this point, only implicit in the earlier draft, explicit.

3. What will seem visually intrusive in the project -- the cooling tower, fencing, or, as you suggest, a light bulb at night -- is obviously a subjective matter. I gave prominence in this report to the cooling towers because they most impressed me in visiting geothermal fields.

4. I am puzzled as to what you write about noise. It is true that the facility now produces no noise -- when the well is closed down. It does make noise when it is flowing. The whole point of the statement about noise in the E.I.S. is that the engineers offer assurances that the noise level for the well hooked up to the generator will be less than what has been experienced heretofore in test flows.

5. Similarly, with respect to H_2S smells, while there is no absolute certainty that a nuisance will be avoided, the project is saying, in good faith, that this is its intention and that there is a high probability that the intention can be carried out.

6. As to fencing, that has been stated to be a factor which is positive, for, again, that is the intent of the project.

Thank you for your comments and suggestions.

Sincerely,

Robert M. Kamins

ROBERT M. KAMINS
Consultant

RMK:ny

cc: Department of Planning and Economic Development

APPENDIX

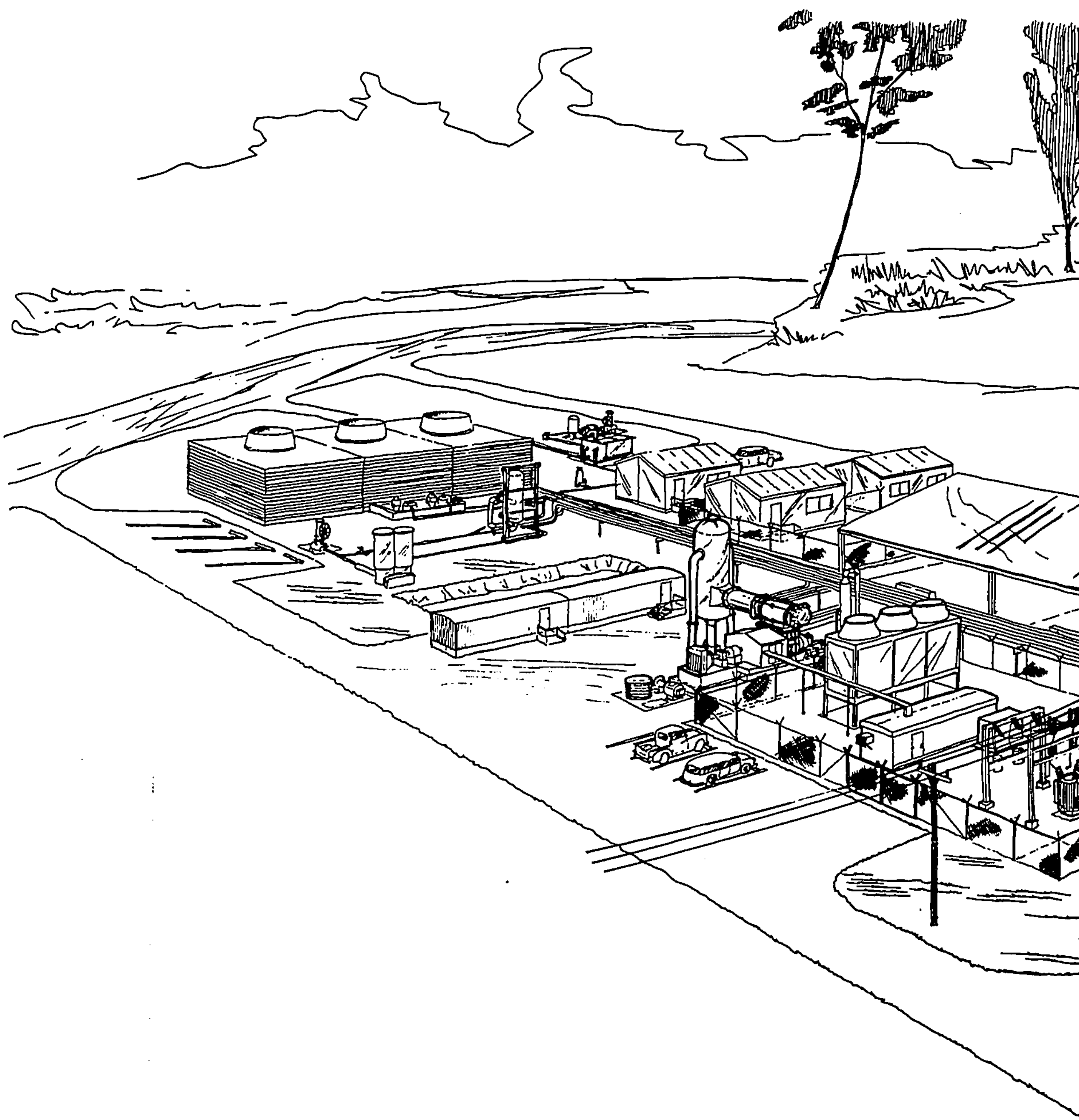
Description of the Facilities Proposed for the Hawaii Geothermal Research Station

[The following description is taken from the grant proposal to the federal Department of Energy to fund a wellhead generator and associated facilities for the project. Although some details are subject to change -- depending on the financing obtained -- the statements are sufficiently firm to give specificity to the project design.]

The Hawaii Geothermal Research Station will consist of the research power plant and a facility to do research and development of electric and non-electric applications of the geothermal resource.

The research power plant will assist the development of geothermal energy in the State of Hawaii through the early demonstration of the generation of electricity from geothermal heat from a young volcanic geothermal reservoir. The project will assist the industrial sector in evaluating and establishing the operational risk levels associated with energy production from such a source, and help to determine the environmental constraints that may be associated with the long-term production of fluids from a typical volcanic geothermal reservoir.

The R&D test facility will consist of up to three test pads and pipes to supply the geothermal fluids to the test pads. The R&D of electric applications will include tests of concepts, hardware components, and sub-systems. A wide range of non-electric applications will be tested, including agricultural applications, such as controlled-environment cultivation; industrial food-processing, such as canning, freeze-drying and processing fruit and fruit-juices; and aquaculture applications, such as raising nehu.



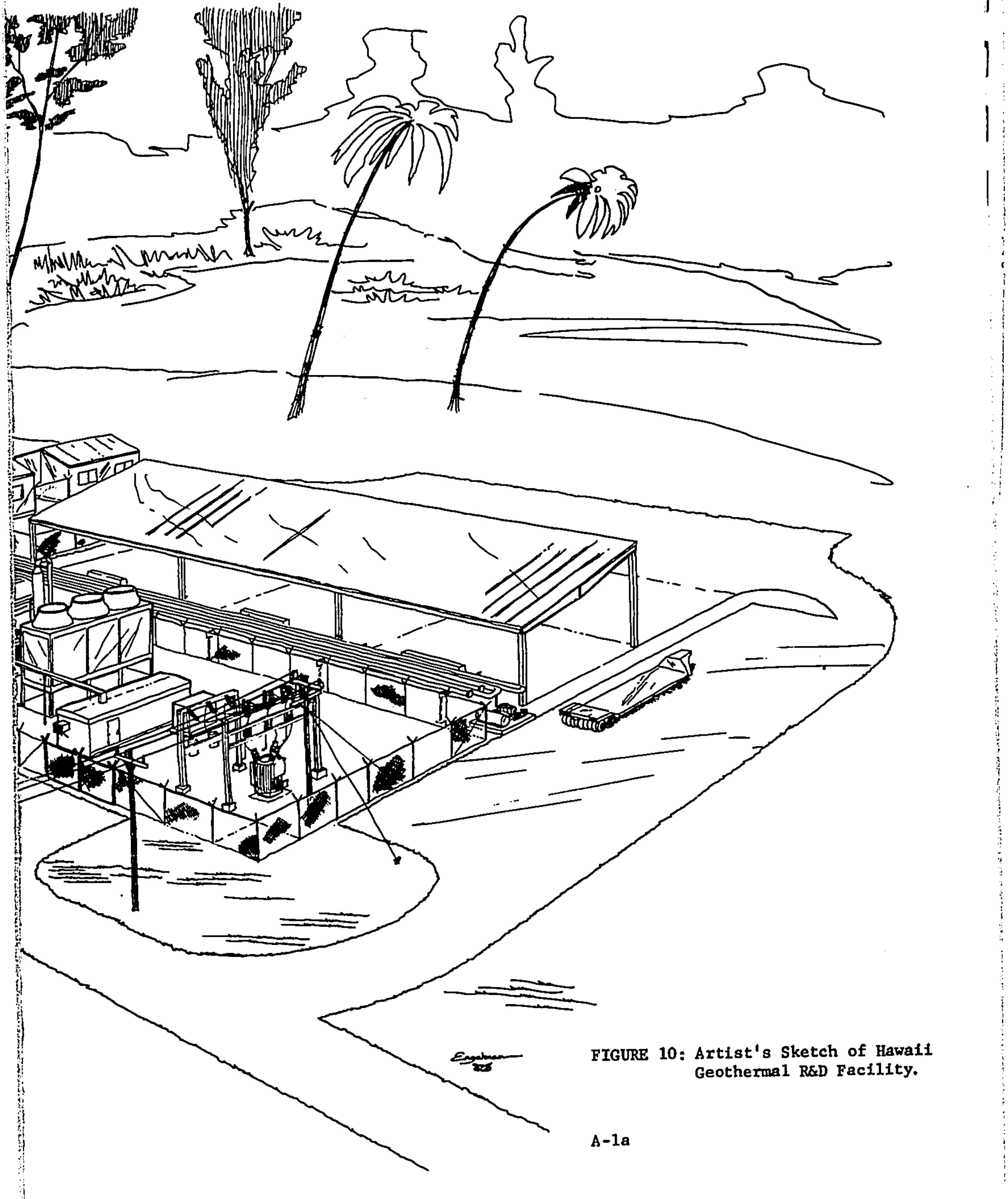


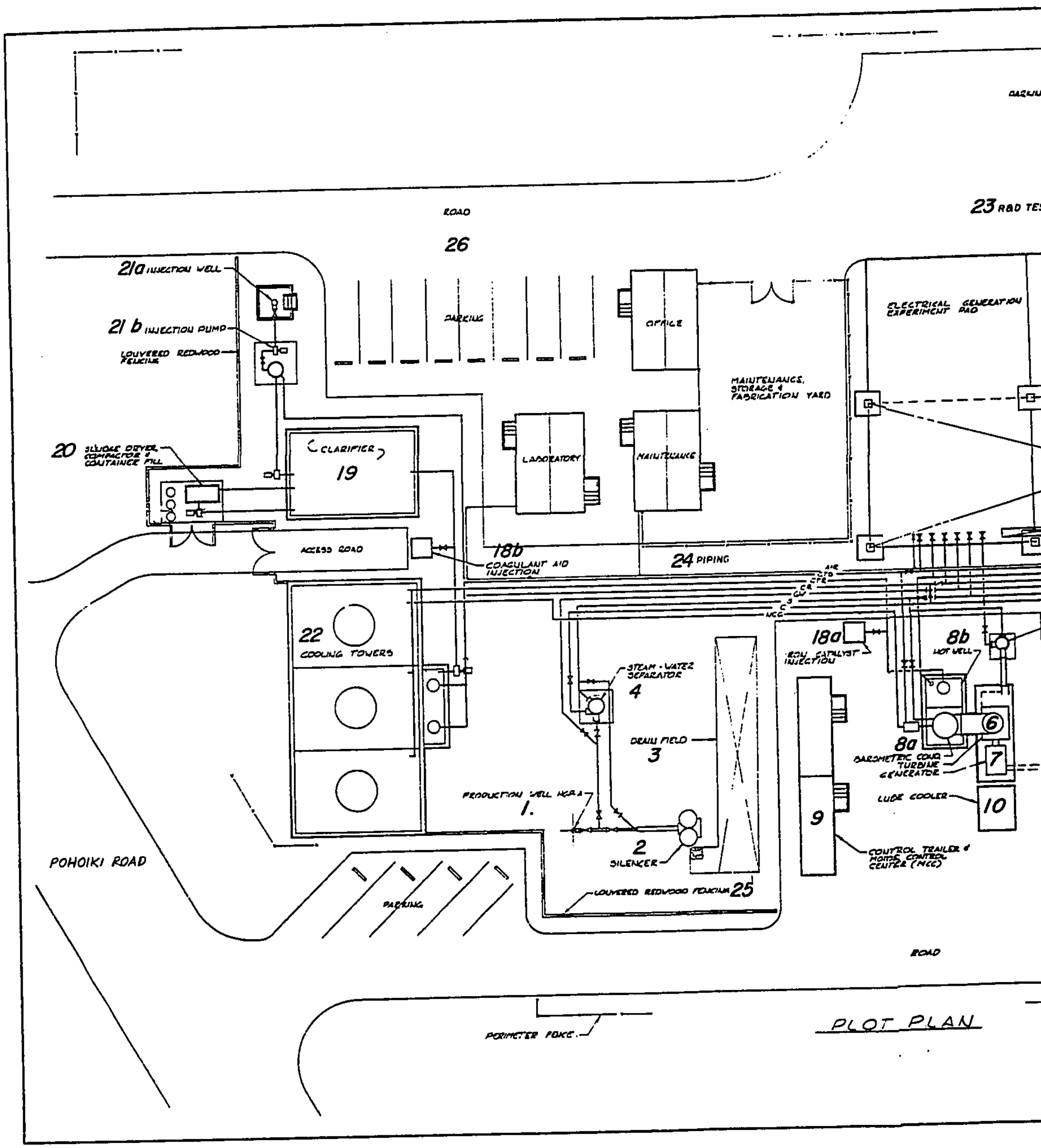
FIGURE 10: Artist's Sketch of Hawaii Geothermal R&D Facility.

General Description

The 4-acre site divides naturally into an upper and lower portion of roughly two acres each. There is presently a plastic-lined water pond on the upper 2-acre portion, which was used to supply water during the drilling of HGP-A.

The general grade of the property appears to fall to the southwest and appears to be very porous and no drainage problems appear imminent. There are two ways that used fluid from the research station could be disposed of, namely, through a drainage pond or through a reinjection well. During the design phase of the project, both methods will be studied and a decision will be made. If a drainage pond is used, it will probably be excavated on the upper portion of the site, which will remain essentially undeveloped.

The facilities indicated are located in an area approximately 200 feet by 400 feet running in a northeast direction from the Pohoiki Road and completely surrounded by a security type chain-link fence. The redwood slatted cooling tower has been placed between the road and all of the equipment to present an esthetically pleasing appearance and to keep the tower downwind of the plant components to prevent water carry-over to the plant. The power plant, consisting of the turbo-generator, demister and barometric condenser, has been located close to the production well and steam separator to keep the insulated, large-size piping lengths as short as possible because of their high cost. Any objectionable noise from the existing silencer in the present location should be muffled from the populated areas by the cooling tower. The switch gear and transformer area is adjacent to the turbo-generator to reduce wire lengths and to take advantage of the adjacent location of the HELCO grid.



ROAD
26
23 R&D TE
21a INJECTION WELL
21 b INJECTION PUMP
LOUVERED REDWOOD FENCING
PARKING
OFFICE
ELECTRICAL GENERATION EXPERIMENT PAD
MAINTENANCE, STORAGE & FABRICATION YARD
20 SLUDGE DRYER, COMPACTOR & CONTAINER FILL
CLARIFIER
19
LABORATORY
MAINTENANCE
ACCESS ROAD
18b COAGULANT AID INJECTION
24 PIPING
22 COOLING TOWERS
18a EDU CATALYST INJECTION
8b HOT WELL
STEAM - WATER SEPARATOR
4
DRAIN FIELD
3
6
8a
BAROMETRIC COND.
TURBINE
GENERATOR
7
LUBE COOLER
10
PRODUCTION WELL HGP-A
1.
9
2
SILENCER
CONTROL TRAILER & MOTOR CONTROL CENTER (MCC)
POHOIKI ROAD
PARKING
LOUVERED REDWOOD FENCING 25
ROAD
PERIMETER FENCE
PLOT PLAN

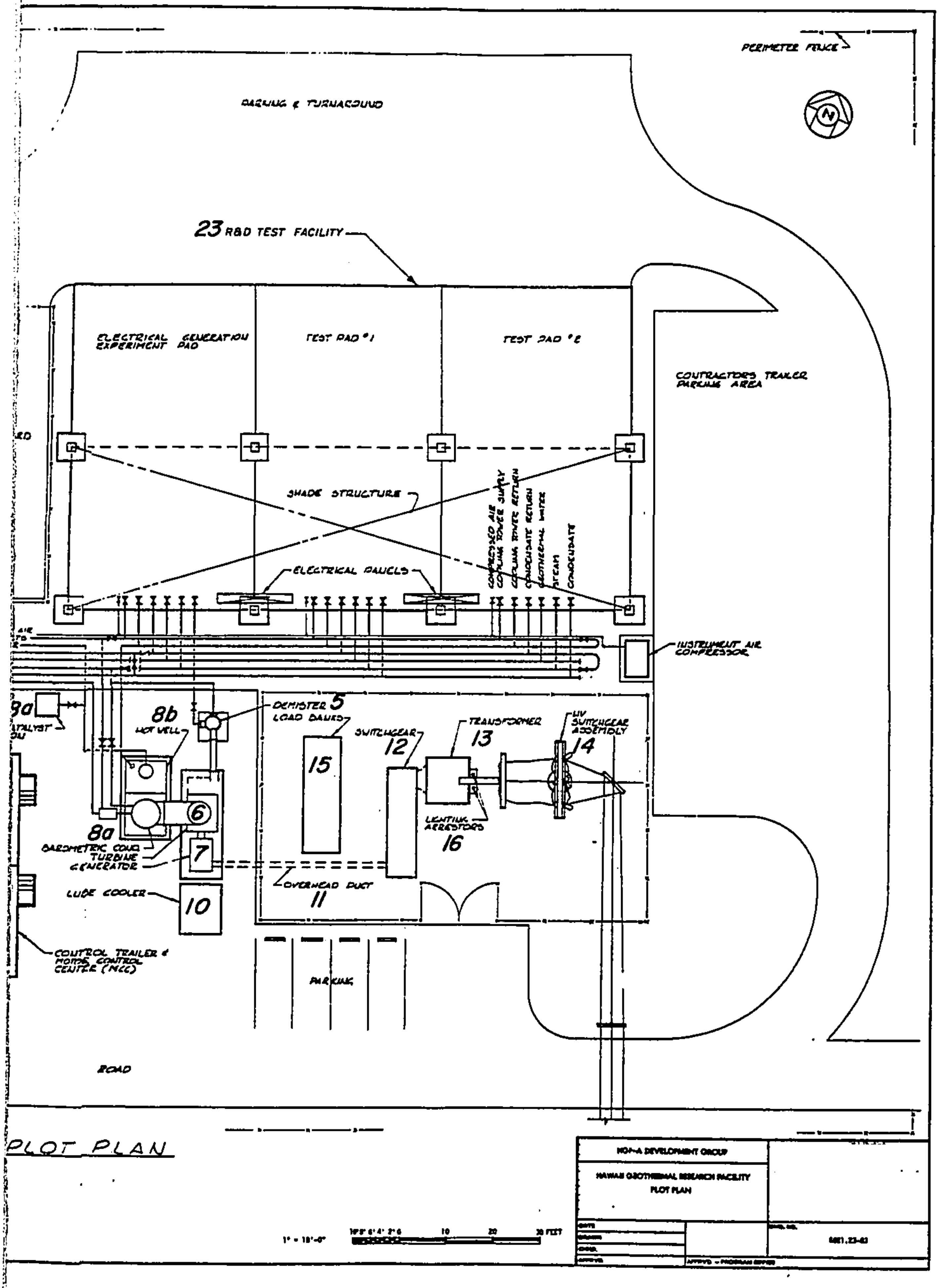


FIGURE 11: Plot Plan of Hawaii Geothermal R&D Facility.

Description and Use of Proposed Facilities

It should be noted that the generator and associated equipment have yet to be selected, and there may be minor variations in the plot plan of the research station when the major items of equipment have been selected and the design phase has been completed. It is anticipated that the design phase will be completed 12 months after the project's start date. Thus, the facilities on the attached plot plan, that are described below, are those that are anticipated for the research station and they closely resemble the equipment that will eventually be installed, but some changes or modifications are probable.

1. Production Well HGP-A

HGP-A is the well drilled to 6,435 feet by the Hawaii Geothermal Project. The fluids from HGP-A will be used to run the turbo-generator system to produce electricity. HGP-A has tested out with temperatures in excess of 600 degrees Fahrenheit, and a wellhead pressure between 60 and 70 p.s.i. This pressure is sufficient to power an electric generating unit of up to 3.8 megawatts. No more than three megawatts of electricity will be sold to the Hawaii Electric Light Co., however, because the transmission line that runs by the HGP-A site cannot handle more than three additional megawatts of power.

Any electric power generated at the station in excess of three megawatts will either be utilized to experiment with electric applications in the R&D test facility or be dissipated in the station's resistive load banks. Valves, gauges, accessories and mounting equipment will be installed on the wellhead to control and monitor fluid flow.

2. Silencer

A silencer will muffle the noise that accompanies the release of geothermal fluids to the atmosphere to prevent a nuisance to the persons living in the vicinity and to protect the personnel working in the area.

3. Drain Field

The drain field is the existing pit into which geothermal fluids from the well are presently discharged. If a reinjection well is drilled or a new enlarged drainage pond is developed, this drain field will no longer be needed.

4. Steam-Water Separator

The function of the steam-water separator is to receive the two-phase fluid as it comes out of the wellhead and separate it into steam and water. The two-phase fluid enters the separator through a tangential inlet duct and by centrifugal action the water is separated at the walls and settles to the bottom of the vessel while the steam rises over a central pipe that serves to exhaust the steam. The liquid phase is exhausted from the vessel and sent to the drainage pond. This piece of equipment will be 25-30 feet high.

5. Demister

A demister is a cylindrical tank with an internal arrangement which promotes a centrifugal separation of particles. The function of the demister is to remove entrained water droplets from the steam, before it enters the turbine. Steam coming from the steam/water separator contains minute quantities of water and dissolved solids. If these droplets are permitted to enter the turbine, they will cause erosion and corrosion problems that will reduce the life of the blades and cause shutdowns and costly maintenance problems. The demister will reduce the moisture content of the steam to a level that can be tolerated by the turbine for long-term operation.

6. Turbine

A condensing turbine will be used in which the steam expands in several stages and supplies shaft power to an electric generator. The turbine will be a 20 to 25-foot high structure.

7. Generator

The generator transforms the mechanical energy from the turbine into electrical energy.

8.a. Barometric Condenser and 8.b. Hot Well

The function of the condenser subsystem is to condense the vapor exhausting from a turbine and reduce the back pressure on the last stage. To accomplish this it is necessary not only to condense the water vapor but also to remove the non-condensable gases that accompany geothermal steam. The condenser subsystem, therefore, consists of a condenser, steam eductors to remove non-condensables, and water supply and pumps.

9. Control Trailer and Motor Control Center (MCC)

These are two transportable 8'x8'x24' building modules, adjacent to the turbo-generator, which house the motor control center and office for the power plant. This building has been isolated from the other support buildings because of the separate function and operation of the power plant.

10. Lube Cooler

This piece of equipment cools off the lubricants for machine bearings.

11. Overhead Duct

The function of the overhead duct is to house the insulated conductors which serve as feeders from the generator to the substation. The feeders from the substation to the station service transformers will be conductors routed in a similar fashion.

12. Switchgear

The generator and low voltage switchgear protects and separates the generator from the transformer. It also supplies the plant with all the low voltage power needed.

13. Transformer

The transformer steps up the low voltage power from the generator to HELCO transmission voltage.

14. HV Switchgear Assembly

The high voltage switchgear assembly protects and separates the transformer from the HELCO system.

15. Load Banks

These load banks will dissipate any excess power generated from the generator system which cannot be transmitted.

16. Lightning Arrestors

These prevent lightning from damaging the facilities and equipment on the power plant site.

17. Instrument Air Compressor

The air compressor system provides compressed air as needed for instrumentation.

18.a. Iron Catalyst Injection and 18.b. Coagulant Aid Injection

The iron catalyst system is an H_2S abatement system which includes the catalyst injection system, the clarifier, transfer pumps, the flocculator/clarifier, and the sludge handling system. The catalyst injection system injects ferric ions (via ferric sulfate) into the cooling water in the cooling towers. The ferric ions react with the dissolved H_2S to yield elemental sulfur, water and ferrous ions. As the cooling water is aerated in the cooling tower, the ferrous ions react with oxygen to reform ferric ions, thus providing continuous regeneration of ferric ions to sustain the H_2S reactions which repeat continuously to yield sulfur. The sulfur thus formed is removed from the system via clarifiers (after flocculation) as a sludge and disposed of in accordance with County regulations. A maximum of 1,000 lbs. per day of sulfur will be produced.

19. Clarifier

The clarifier is a partially buried, pre-assembled steel tank in close proximity to the injection pumps and well, and also close to the clarifier sludge handling system located on the access road for easy removal of the sludge.

20. Sludge Dryer, Compactor and Container Fill

See "Iron Catalyst Injection" above.

21.a. Injection Well and 21.b. Injection Pump (Not in current planning)

The injection well and injection pump are used to reinject all geothermal fluids extracted from the resource less those used for research and demonstration applications or evaporated in the cooling tower.

22. Cooling Towers

The function of the cooling tower is to provide the water required to condense the vapor that is exhausted from the turbine, and the vapor that enters the interstage condensers of multiple stage gas ejectors. This is accomplished by cooling the water, including the condensate, from the condensation temperature (115°F) to the condenser feed water temperature (85°F). The cooling is done by the evaporation of water which occurs when air is passed through a curtain of falling condensate/cooling water. Cooling towers will be the most visible pieces of equipment at the research station because of their relatively large size.

The cooling tower depicted in the plot plan is composed of three modules, each of which is 60.5 by 29 feet, 18 feet high, and sits in a concrete basin 1.5 feet deep. Another type of cooling tower that could be utilized is a 36-foot square unit within a total height of 53 feet.

The water which will be used for the initial fill of the cooling tower system and used for the make-up of the cooling tower will be water that is produced by the existing production well in the form of condensation from the separator and from the turbine generator. Because the geothermal water analysis indicates that the water has a relatively low concentration of salts or other impurities (other than the H_2S), the geothermal water will be more than satisfactory for the cooling systems and any search for additional or alternate sources of cooling water is not necessary.

23. R&D Test Facility

The research test facility will be designed to accommodate experiments in electric and non-electric applications in support of local, State, and national needs to develop and utilize geothermal energy. The test facility will consist of up to three test pads, one of which will be designed specifically to test energy conversion systems. The test pads will have concrete floors and each pad will be approximately 35 feet square. All test pads will be supplied with three geothermal fluid types (steam, hot brine, and a bi-phase mixture of steam and saturated water) for optional use by experimenters. In addition, electrical services, cooling water and compressed air will be provided to the test pads, as will instrumentation to monitor the temperature, pressure and flow of the geothermal fluids.

The test pads will be covered by a roof to protect the test equipment from the rain.

24. Site Piping

Piping will be routed throughout the site on elevated pipeways. Pipe, pipe supports, and pipeway structures will be designed and painted and coded in such a manner as to permit efficient maintenance procedures.

Lines carrying hot fluids will be insulated for both personnel protection and heat conservation. Expansion joints or expansion loops and pipe anchors will be utilized where required. Vibration isolators will be used on pumps and air compressors. Bypasses and flanged connections will be used on control valves, flow orifices, and other equipment where frequent calibration or maintenance may be required.

25. Louvered Redwood Fencing

Slatted redwood architectural screens and selected plants will be placed around the site of the research power plant to mask the industrial appearance of the equipment.

26. Roads, Parking and Security

The access road and plant roads will be designed to handle the legal maximum length for highways of semi-trailers (55 feet).

Parking will be provided in close proximity to each of the operating functions of the research facility, as indicated in the plot plan. Parking areas and roads will be paved.

In addition to the entire area being surrounded by a fence, the switchgear yard and the maintenance and work yard are further protected with an 8-foot chain-link fence and barbed wire.

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